

**REMEDIAL INVESTIGATION REPORT
FOR
LITTLE SCIOTO RIVER AND BAKER WOOD
CREOSOTING SITES
MARION, MARION COUNTY, OHIO**

Prepared for



Prepared by





August 2, 2013

Mr. Howard Caine
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**Subject: Final Remedial Investigation Report for Little Scioto River and Baker Wood
Creosoting Sites - Marion, Marion County, Ohio
Contract No. EP-S5-06-02, Work Assignment No. 155-RICO-B5BC**

Dear Mr. Caine:

SulTRAC is submitting the enclosed final remedial investigation (RI) report for the Little Scioto River (LSR) and Baker Wood Creosoting (BWC) sites in Marion, Marion County, Ohio. As requested, the RI report includes information on LSR and BWC. The final RI report addresses comments received from EPA Region 5 and Ohio EPA on February 28, 2013.

Please note that SulTRAC did not make one text change as was noted in our Response to Comments document dated May 7, 2013. On page 7 of the document, SulTRAC stated that on pages 2-58 and 2-59 of the human health risk assessment, language in the text would be modified to read "This parameter is used to estimate dermal exposures to groundwater for organic constituents for which ET is less than or equal to t*". After further investigation, SulTRAC determined that the original language in the text was correct and did not require a modification. All other issues related to that comment were addressed.

If you have any questions about the final RI report, please call me at (513) 333-3672.

Sincerely,

A handwritten signature in black ink that reads "Jodi McCarty".

Jodi McCarty
SulTRAC Project Manager

Enclosure

cc: Parveen Vij, EPA Contracting Officer (letter only)
Mindy Gould, SulTRAC Program Manager (letter only)
File

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FOR
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**Prepared for
U.S. Environmental Protection Agency
Region 5
77 West Jackson
Chicago, Illinois 60604**

Work Assignment No.	:	155-RICO-B5BC
Contract No.	:	EP-S5-06-02
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ACRONYMS AND ABBREVIATIONS

µg/kg	Micrograms per kilogram
µg/L	Micrograms per liter
µmole/g	Micromoles per gram
AEC	Anion exchange capacity
ALM	Adult lead model
atm m/mole	Atmospheres meter per mole
ATSDR	Agency for toxic Substances and Disease Registry
AVS/SEM	Acid volatile sulfide/simultaneously extracted metals
BaPE	Benzo(a)pyrene equivalents
BCF	Bioconcentration factor
BERA	Baseline ecological risk assessment
bss	Below sediment surface
BWC	Baker Wood Creosoting
bgs	Below ground surface
CalEPA	California Environmental Protection Agency
cm/sec	Centimeters per second
COI	Chemical of interest
COPC	Chemical of potential concern
COPEC	Chemical of potential ecological concern
CSM	Conceptual site model
CSO	Combined sewer overflow
CTE	Central tendency exposure
DG	Deep groundwater
DNAPL	Dense nonaqueous phase liquid
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
ERA	Ecological risk assessment
ERAGS	Ecological Risk Assessment Guidance for Superfund
ESI	Expanded site investigation
ESL	Ecological screening level
ESV	Ecological screening value
FCM	Food chain model
FIELDs	Field Environmental Decision Support
<i>foc</i>	Fraction of organic carbon

FS	Feasibility study
FSP	Field sampling plan
gpm	Gallons per minute
GPR	Ground penetrating radar
GPS	Global positioning system
HEAST	Health Effects Assessment Summary Tables
HHRAP	Human Health Risk Assessment Protocol
HHSL	Human health screening level
HQ	Hazard quotient
IA	Integrated assessment
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
Koc	Organic carbon-water partitioning coefficient
Kow	Octanol-water partitioning coefficient
Ksp	Solubility product
LDR	Land disposal restrictions
LIF	Laser induced fluorescence
LNAPL	Light nonaqueous phase liquid
LSR	Little Scioto River
MCL	Maximum contaminant level
meq 100g	Milliequivalents per 100 grams of soil
mg/kg	Milligrams per kilogram
mole/L	Millimoles/liter
MRL	Minimum risk levels
msl	Mean sea level
NAPL	Nonaqueous phase liquid
NRD	North Rockswale Ditch
NTU	Nephelometric turbidity unit
ODOH	Ohio Department of Health
Ohio DNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
ORP	Oxygen reduction potential

PAH	Polycyclic aromatic hydrocarbon
PID	Photoionization detector
ppm	Part per million
PPRTV	Provisional Peer Reviewed Toxicity Values
PVC	Polyvinyl chloride
R _d	Retardation factor
RAC	Response Action Contract
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial investigation
RME	Reasonable maximum exposure
RSL	Regional screening level
R/T	Release/transport
SAP	Sampling and analysis plan
SB	Sediment benchmark
SG	Shallow groundwater
SI	Site inspection
SLERA	Screening level ecological risk assessment
SQL	Sample quantitation limit
SS	Surface soil
SVOC	Semivolatile organic compound
TAL	Target analyte list
TarGOST	Tar-specific Green Optical Screening Tool
TCL	Target compound list
TCLP	Toxicity characteristic leaching procedure
TOC	Total organic carbon
TRV	Toxicity reference value
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VDEQ	Virginia Department of Environmental Quality
VOC	Volatile organic compound

1.0 INTRODUCTION

SulTRAC prepared this remedial investigation (RI) report for the U.S. Environmental Protection Agency under the EPA Remedial Action Contract No. EP-S5-06-02 (RAC 2), Work Assignment No. 155-RICO-B5BC. Under this work assignment, the EPA tasked SulTRAC to perform a RI at the Little Scioto River (LSR) and Baker Wood Creosoting (BWC) sites. Specifically, SulTRAC reviewed historical information, conducted sampling activities, and prepared this RI report in accordance with applicable EPA guidance (EPA 1988).

The RI was designed to be conducted using the Triad approach (where applicable). This type of approach relies on data-driven decisions; thus, the investigation was dynamic. Consistent with the Triad methodology, SulTRAC compiled sampling data and evaluated the usability of data collected on a real-time basis that enabled distance collaboration between the field team and other stakeholders not present on site. Updates were provided to the EPA and the Ohio Environmental Protection Agency (Ohio EPA) during the duration of the field investigation.

The primary goals of the RI are to (1) further define the extent of contaminated sediment in the LSR, (2) quantify the risk to human health and the environment posed by sediment in the LSR, (3) delineate the nature and extent of soil and groundwater contamination, if any, on the BWC site, (4) evaluate whether non-aqueous phase liquid (NAPL) is present at the BWC site, and (5) quantify the risk to human health and the environment posed by soil and groundwater at BWC. Information presented in the RI report will be used as the basis for completing a feasibility study (FS) that will estimate volumes of sediment, soil, or groundwater that may require remediation. The FS will also evaluate various technologies, develop these technologies into potential remedial alternatives, and evaluate potential remedial alternatives to address actual or potential risk posed by contaminants present at LSR or BWC.

The RI consisted of two parallel field investigations. One investigation was focused in and adjacent to the LSR itself, and another investigation was focused on the former BWC property. The two investigation areas are related because the river was affected by historical operations at and discharges from BWC. The LSR field investigation was conducted in October and November 2010. The BWC field investigation was conducted in April 2011, with additional investigations conducted in August and November 2011 and February 2012.

The LSR investigation focused on (1) verifying whether residual polycyclic aromatic hydrocarbons (PAH) and metals contamination in river segments previously addressed by EPA during the removal action are below

screening levels, (2) further characterizing surface water and sediment quality in the river and in low-lying areas adjacent to the river, (3) assessing whether any unidentified upstream sources of contamination from connecting waterways exists, and (4) collecting additional background data for comparison purposes. In addition, a limited groundwater investigation was conducted adjacent to the river to (1) evaluate the hydraulic connection between the LSR and shallow groundwater, and (2) assess whether any impacts to shallow groundwater have resulted from contaminants potentially leaching from sediment to groundwater. The BWC soil investigation focused on (1) characterizing surface and subsurface soil conditions in areas other than those addressed by EPA during the removal action, (2) evaluating whether grossly contaminated soil or creosote source material still exists at the site, (3) evaluating whether the on-site slag pile contains leachable and hazardous compounds, and (4) obtaining background data for comparison purposes. The BWC groundwater investigation focused on (1) identifying whether any dissolved- or free-phase contaminants are affecting site groundwater, (2) characterizing site water-bearing zones, (3) obtaining groundwater elevation measurements and determining the flow direction for site groundwater, and (4) determining if shallow groundwater is contaminating the bedrock aquifer.

1.1 LSR SITE BACKGROUND AND HISTORY

The following sections provide a description of the LSR and a summary of historical activities that have been conducted at the LSR.

1.1.1 Site Description

The LSR site is located just west of the City of Marion, Ohio (see Figure 1). The LSR flows north to south and feeds the Scioto River, a major tributary to the Ohio River (see Figure 2). The LSR site area is approximately 8.5 river miles, including 1.5 miles of North Rockswale Ditch (NRD), 2.2 miles of Rockswale Ditch, 1.1 miles of Columbia Ditch, and 1.4 miles of Unnamed Ditch. The LSR investigation area begins at the State Route 309 bridge and extends to the Scioto River confluence just south of Green Camp, Ohio. The LSR is located in a primarily low-density residential area with unrestricted access via farm fields, bridges, state-designated recreation areas, and wildlife areas. The LSR is a low-velocity, high-turbidity river that ranges between 19.7 and 49 feet wide and 1.6 and 4.9 meters deep. The streambed consists primarily of sand with increasing clay/silt fractions downstream (Ecology and Environment 2000). The topography of the surrounding land area is generally flat (slopes of 0 to 2 percent) with a slight decline toward the river.

1.1.2 Site History

The LSR received historical discharges from the former BWC facility via the NRD. The BWC site operated as a lumber preserver from the 1890s until the 1960s. A combined sanitary and storm sewer was located along the southern border of the BWC site along Holland Road. The sewer travelled west beneath Holland Road and discharged into NRD (see Figure 2). NRD flows west approximately 0.5 mile before it discharges into the LSR. In the 1940s, the Ohio Department of Health (ODH) indicated that chemicals from the BWC site were being discharged into the combined sewers that drained into NRD and the LSR.

In 1987, the Ohio EPA conducted a biological and water quality study of the LSR and its tributaries (Ohio EPA 1988). The results of the study concluded that heavy metals and organics contamination had caused severe biological and water quality degradation in the downstream portion of LSR, Rockswale Ditch, and Columbia Ditch.

On March 20, 1992, ODH issued an advisory against swimming in, wading in, and eating fish caught from a 4-mile length of the LSR, west of the City of Marion from Holland Road south to State Route 739. ODH, in cooperation with Ohio EPA and the Ohio Department of Natural Resources (Ohio DNR), issued consumption advisories under Ohio law (Ohio Revised Code Chapter 3701). The Ohio sport fish consumption advisory recommended not eating any fish from this area because of the PAH contamination.

From August 1992 to February 1993, Ohio EPA conducted a biological, sediment, and water quality study of the LSR and its tributaries (Ohio EPA 1994). The results of the study were consistent with the 1988 report, concluding that heavy metals and organics contamination had caused severe biological and water quality degradation in downstream portions of the LSR.

In 1998, Ohio EPA conducted a biological and water quality study of the Marion area streams (Ohio EPA 2000). The LSR and its tributaries were included in this study. The results of the study confirmed previous sample results reported by Ohio EPA in 1994, that the majority of the LSR will not support aquatic life. The study identified a severely metals- and PAH-contaminated section of the LSR beginning at Holland Road and continuing 4 miles downstream. Contaminated sediments, combined with sewer overflows, low dissolved oxygen, and elevated ammonia (as nitrogen), were associated with substantial impairment of fish and macroinvertebrate communities in the lower 6 miles of the LSR. The levels of PAH contamination documented

in 1998 were comparable to previous studies, which prompted ODH to issue advisories on fish consumption and primary contact for the lower section of the LSR.

From May 1999 through May 2000, the EPA conducted a removal site evaluation of the NRD and LSR pertaining to creosote contamination. The study concluded that approximately 4 miles of the LSR and 0.5 mile of the NRD were contaminated with creosote, resulting in an estimated 40,000 cubic yards of contaminated sediment (see Figure 3). Additional information can be obtained from the report titled *The Little Scioto River and North Rockswale Ditch Assessment*, prepared for the EPA by Ecology and Environment, Inc., dated May 25, 2000.

On June 10, 2002, the EPA mobilized to the LSR site to perform a time-critical removal action. From June 10 to December 18, 2002, approximately 7,500 cubic yards of contaminated sediment were excavated from approximately 2,800 feet of the NRD and approximately 17,840 cubic yards of contaminated sediment were excavated from approximately 2,900 feet of the LSR. Contaminated sediment was staged at two different locations. Each staging and stabilization pad was lined and diked. One was located at the intersection of Holland Road and the LSR, on the park property and the second pad was constructed at the Marion Waste Water Treatment Plant located on State Route 95. From May 27 through July 17, 2003, the excavated (approximately 42,000 tons) creosote-contaminated (nonhazardous) sediment was transported from the on-site storage areas and disposed of at an off-site landfill. Phase I of the removal action was conducted under the Oil Pollution Act authority and concluded in August 2003.

On May 22, 2006, the EPA began Phase 2 of additional cleanup at the LSR. EPA mobilized its contractors to continue with removal activities in the LSR. Phase 2 was completed on September 28, 2006. Approximately 23,000 cubic yards (about 31,000 tons) of contaminated sediment was removed from 2,800 feet of the LSR. The EPA and Ohio EPA estimated that about 3.25 miles of the LSR still contained grossly contaminated sediment after Phase 2 was completed (see Figure 3).

In 2007 and 2008, Ohio EPA conducted an additional site inspection (SI) and expanded SI (ESI) (Ohio EPA 2007 and 2008) for the LSR site. Soil, sediment, surface water, and groundwater samples were collected. These investigations concluded that portions of the LSR continue to pose a threat to human health and the environment from historical discharges from the BWC property.

Figure 4 presents sampling locations along the LSR and adjoining waterways previously sampled by the EPA and Ohio EPA.

1.2 BAKER WOOD CREOSOTING SITE BACKGROUND AND HISTORY

The following sections provide a description of the BWC site and a summary of historical activities that have been conducted at the BWC site.

1.2.1 Site Description

The former BWC site is located at the northwestern corner of the intersection of State Route 309 and Holland Road in Marion, Marion County, Ohio (see Figure 1). The geographic coordinates for the site are latitude 40°35'37" North and longitude 83°09'20" West. The BWC site encompasses approximately 60 acres. The site is located in a mixed residential, agricultural, commercial, and industrial area (see Figure 5). The BWC site is bordered to the south by Holland Road. Union Tank Car, a railcar cleaning facility, exists south of Holland Road. A combined sanitary and storm sewer located along the southern border travels beneath Holland Road, flowing west, and discharges directly into NRD. NRD flows south under Holland Road to the combined sewer outfall gate, then turns west and flows directly into the LSR. The BWC site is bordered to the north by agricultural land, followed by residential areas mixed with agricultural fields. To the east, the BWC site is bordered by State Route 309, followed by mix residential and industrial areas. The BWC site is bordered to the west by an agricultural field, followed by a residential property. The eastern portion of the BWC property is more open land, not heavily vegetated, and contains the former bioremediation area and the former processing area (when operations were active). The eastern portion is mainly overgrown weeds and grass with limited trees and some concrete footers. The western portion of the BWC property is a dense wooded area and is where the former drying area was located (when operations were active). The BWC property is within an area subject to minimal flooding, but not in a flood zone.

1.2.2 Site History

The former BWC operated as a lumber preserver from the 1890s until the 1960s. Lumber, including railroad ties, was preserved with coal tar creosote, petroleum, and other solvents in pressurized tanks. An 1892 Sanborn insurance map indicates that railroad ties were preserved with coal-tar creosote in the processing area on the eastern third of the property and then stacked to dry on the western portion of the BWC property. The facility possibly used the procedure to treat wood in pressurized cylinders with

creosote, in combination with petroleum and other solvents. Sewer tie-ins from the BWC property were the likely transport mechanism for creosote discharging off the property.

On September 4, 1946, ODH first cited BWC as a contributor of contamination to surface water. In a letter dated December 4, 1946, ODH informed BWC that it should install a waste treatment system. The waste treatment system was put into place in 1953. After the waste treatment system had been installed, ODH documented continued discharge of creosote material from the BWC property. Subsequent letters from ODH urged the company to cease any operations that affected the water quality in the LSR.

From 1970 until the early 1990s, the eastern portion of the BWC property was used by Sims Brothers, Inc. (Sims), as a scrap metal salvage yard for railroad tank and boxcars. Sims purchased the property from D.B. Frampton Company, and Sims later formed the Baker Wood Limited Partnership, which became the owner of the property. It is not known what type of practices occurred during the salvage operations.

The site has been vacant since the early 1990s.

In October 1991, Ohio EPA's Site Investigation Field Unit conducted an investigation on the BWC property. The purpose of this investigation was to collect field data necessary to establish the presence of hazardous constituents on the BWC property that had been migrating or continued to migrate off site and to sensitive receptors. The investigation concluded that PAHs were present in soils at the BWC property. However, the investigation was inconclusive as to determining whether contamination from the BWC site migrated off site to the LSR.

On March 20, 1992, ODH issued an advisory against swimming in, wading in, and eating fish caught from a 4-mile length of the LSR, from Holland Road south to State Route 739. The Ohio sport fish consumption advisory recommended not consuming any fish from this stretch of the LSR because of the PAH contamination found at the BWC property.

In 1996, Ohio EPA performed an integrated assessment (IA) at the BWC property. Ohio EPA sampled and analyzed the water in the combined sewer, as well as the sediment in NRD. Analytical data confirmed the presence of volatile organic compounds (VOC) and PAHs, directly related to coal tar creosote in NRD and LSR. According to the Ohio EPA IA report, extremely high levels of VOCs and PAHs were detected in waste buried or partially buried at the BWC property (Ohio EPA 2006).

On December 2, 1998, Ohio EPA met representatives from the EPA Technical Support Unit and Ohio State University at the BWC property to conduct a site reconnaissance for a future geophysical survey. Previously, ODH had identified BWC as a contributor to the contamination in NRD and LSR. The purpose of the geophysical survey was to delineate the extent of contamination at the BWC property. The proposed geophysical survey area, approximately 250 feet by 1,500 feet, included the former processing area. On January 21, 1999, EPA set up a grid and used a ground penetrating radar (GPR) unit and an electromagnetic survey unit. The former processing area was surveyed using a grid (100 feet by 300 feet) with a line spacing of 3 feet. The results of the survey indicated that a majority of the contamination existed in the former process area.

In April 1999, EPA initiated time-critical removal activities at the BWC property. Initial test trenches were dug to delineate the extent of contamination. Approximately 2,742 cubic yards (3,565 tons) of creosote-contaminated soil was excavated from the former processing area and disposed of off site at EQ Wayne Disposal located in Belleville, Michigan. The contaminated material was removed from the property to eliminate the potential for further migration of contaminants to NRD and LSR. During removal activities, several creosote-contaminated drainage tiles and sewer tie-ins were also removed from beneath the former BWC property to prevent further migration of contaminants to the sewer and subsequently to NRD. The excavated areas were backfilled with clean soil, graded, and seeded to restore site vegetation.

From May 17, 1999, to May 20, 1999, the EPA conducted additional test excavations to determine the remaining extent of contamination, if any, present on site. During trenching, four additional areas of contamination were identified. The four areas revealed creosote waste and heavily contaminated soils, primarily east and northeast of the former processing area. Approximately 3,000 tons of additional waste and contaminated soil were excavated and staged. Land Disposal Restrictions (LDR) instituted on May 12, 1999, mandated that listed creosote wastes could no longer be placed in any type of landfill unless they met LDR limits. This restriction applied to the EPA removal actions that were under way at the time. Therefore, contaminated sediments from surface water bodies and contaminated soils were staged on site in windrows for bioremediation. The windrows were treated with nutrients to accelerate the biological degradation of the contaminants. Periodic sampling of the windrowed soils was performed and revealed the process was fairly effective. PAH concentrations in the windrowed soils on site significantly decreased because of the bioremediation actions. From January 2000 to June 2001, PAH concentration

averages had dropped from approximately 15,000 parts per million (ppm) to 2,000 ppm total PAHs. On September 27, 2001, all EPA personnel and equipment were demobilized from the BWC site.

In November 1999, before the treatment cell had been completed, the EPA installed five groundwater monitoring wells screened in the shallow unconsolidated aquifer. The presence of shallow bedrock across the site indicated that creosote contaminants had the potential to find a pathway to groundwater flowing in the lower, limestone aquifer. Because of this possible migration route, four additional groundwater monitoring wells were installed in September 2002 and screened deeper in the upper portion of the limestone bedrock. The deeper monitoring wells were installed on both the east and west sides of the bioremediation area, as well as the western portion of the site and the northeastern corner of the site (see Figure 5).

Ohio EPA conducted an expanded site inspection at the BWC site in October 2002 after the 1999 removal action was completed at BWC. Ohio EPA field personnel collected 20 samples from on-site soils and groundwater (see Figure 6). Soil samples collected east of the former processing area appeared to be significantly contaminated by site operations, especially at depths of 0- to 2-feet below ground surface (bgs). Numerous semivolatile compounds and metals were detected in soil samples collected at shallow and deep intervals. Two of the shallow monitoring wells contained detectable concentrations of volatile organic compounds and semivolatile organic compounds (SVOC). No VOCs were detected in the deep monitoring wells. Low concentrations of metals were detected but not at concentrations exceeding drinking water standards. The investigation concluded that the BWC property was no longer a threat of discharging to the sewer; however, the groundwater pathway was still a concern since the City of Marion obtains its drinking water from the LSR and Scioto River and from groundwater wells in the area (Ohio EPA 2003).

In July 2003, EPA completed bioremediation and disposed of the bioremediated soils off site. The soils beneath the bioremediation area were not included in the surface and subsurface investigation conducted by the EPA removal program since active treatment was ongoing at that time; however, based on historical information, those soils were also believed to contain elevated concentrations of PAHs and possibly other contaminants.

1.3 REPORT ORGANIZATION

This report includes historical information as well as information obtained during the RI for both the LSR and BWC sites. The report is organized into eight major sections. Each section is arranged to discuss

information relevant to LSR first, followed by information relevant to BWC. Section 1.0 provides a summary of historical activities that have occurred at the LSR and the BWC sites. Section 2.0 provides a summary of sampling activities conducted at the LSR and BWC sites for the RI. Section 3.0 provides a summary of the physical characteristics of both sites. Section 4.0 discusses the nature and extent of contamination for LSR, followed by a discussion of the nature and extent of contamination for the BWC site. Section 5.0 discusses the contaminant fate and transport mechanisms for both LSR and BWC. Section 6.0 provides a summary of the human health risk assessment conducted for LSR and BWC. Section 7.0 provides a summary of the ecological risk assessments conducted for LSR and BWC. Section 8.0 provides a summary of all activities and assessments conducted at the LSR and BWC sites as well as conclusions for each site. References are located in Section 9.0. Figures are located after Section 9.0. Tables can be found in the appropriate appendices that follow the figures.

2.0 RI ACTIVITIES

The following section presents activities conducted at the LSR and BWC sites during RI sampling events. Activities were conducted in accordance with the LSR and BWC planning documents (SulTRAC 2009 and 2010a) and the EPA-approved SAP (SulTRAC 2010b).

2.1 LSR SUMMARY OF RI ACTIVITIES

From October 19 through November 12, 2010, SulTRAC conducted sediment, surface water, fish and invertebrate, and groundwater sampling as part of the RI at the LSR site. During the RI sampling event, the following samples were collected:

- 40 sediment and 35 surface water samples were collected from the LSR and adjoining ditches
- Seven surface soil and sediment samples were collected from floodplains and former oxbow lakes near the LSR
- 50 fish carcass and tissue samples were collected from the LSR
- Nine invertebrate (mussel) samples were collected from the LSR
- 20 groundwater samples were collected from four general locations near the LSR

A detailed discussion of the field sampling activities is provided below. Figure 7 shows all of the LSR RI sampling locations. Tables 2-1 through 2-4 summarize specific sampling activities.

The LSR planning document (SulTRAC 2009) portioned the LSR into four investigation areas:

- LSR and NRD – Segments Previously Addressed by Removal Action
- LSR – From Removal End Point to Confluence with Scioto River
- Other Potential Sources of Contamination – Rockswale Ditch, Columbia Ditch, and Unnamed Ditch
- Background – LSR and NRD

For purposes of the RI report, the LSR was portioned into five exposure areas, which correspond to the exposure areas used for the risk assessments (see Figure 7). The five exposure areas include the following LSR segments:

- LSR-UP1 – This exposure area includes the portions of the LSR and NRD upgradient of the previous removal action.
- LSR-DWN1 – This exposure area includes the portions of the LSR and NRD addressed during the previous removal action.

- LSR-DWN2 – This exposure area includes the portion of the LSR where visual contamination was identified during previous investigations.
- LSR-DWN3 – This exposure area includes the portion of the LSR down to the confluence with the Scioto River where no visual contamination was observed during previous investigations.
- LSR-DWN4 – This exposure area includes the ditches and waterways adjacent to LSR, including Rockswale and Columbia Ditches.

In addition, low-lying surface soil samples were collected along the LSR. The surface soil samples do not in themselves represent an exposure area, but instead are included in the corresponding exposure areas identified above.

2.1.1 Sediment and Surface Water Sampling Activities

From October 19 through 29, 2010, SulTRAC, with assistance from the EPA Field Environmental Decision Support (FIELDS) Team, collected collocated sediment and surface water samples from the Little Scioto River, Rockswale Ditch, North Rockswale Ditch, and Columbia Ditch (see Figure 7). Sampling activities on the LSR commenced near the confluence of the LSR and the Scioto River and progressed upstream. Sediment and surface water locations were mainly accessed using a johnboat with a small motor. Other locations were accessed by walking to the location. Sediment and surface water locations were selected based on the LSR field sampling plan (FSP) (SulTRAC 2010b). The pre-determined locations were downloaded by EPA FIELDS into a global positioning system (GPS) unit and used to find the approximate location for sediment and surface water samples.

Once at the sampling location, a water quality meter was submerged in the river to obtain in-stream water quality parameter measurements of dissolved oxygen, temperature, pH, and specific conductance in the bottom third of the water column. After water quality parameters were measured, surface water samples were collected from the lower third of the water column, when possible, by directly immersing a 1-liter unpreserved glass jar to the desired sampling depth. Once the glass jar was at the desired depth, it was then uncapped and allowed to fill. The glass jar was then used to fill pre-preserved containers. Once the pre-preserved containers were filled the glass jar was refilled for SVOC analysis. Surface water samples collected were submitted for laboratory analysis of metals, cyanide, mercury, hardness, and SVOCs. The samples were immediately placed on ice and processed for shipping at the end of the day. Table 2-1 tabulates surface water sampling locations based on exposure areas and the corresponding analysis.

Table 2-1
Summary of Surface Water Sampling

Location	Samples and Sampling Points	SVOCs, Metals, Cyanide, Mercury, and Hardness
LSR-UP1	6	6
LSR-DWN1	6	6
LSR-DWN2	11	11
LSR-DWN3	8	8
LSR-DWN4	4	4
Total	35	35

Immediately after a surface water sample was collected, a collocated sediment sample was collected at the same sampling location. Sediment samples were collected by pushing down a 2-inch-diameter sampling liner into the sediment by hand, or if pushing was too difficult, by a hammer, then removing the sample by hand. A cap was placed on top of the sampling liner to create suction to keep the sample in the liner. The sample depth was measured and recorded on a field sheet along with the sediment description (Appendix A). The process was repeated at three points across the stream transect. Sediment removed from the liner was placed in a stainless steel mixing bowl and homogenized with other locations along the corresponding stream transect. The top 6 inches of sediment was sampled at every location. In areas downstream of visual contamination (LSR-DWN3 and LSR-DWN4) a deeper interval was sampled, and in contaminated areas (along LSR-DWN2), a deeper interval was sampled in addition to the first 6 inches if visual contamination was present. Sediment collected was placed in non-preserved glass jars for laboratory analysis of SVOCs, metals, cyanide, mercury, and total organic carbon (TOC). Five samples were collected for acid volatile sulfide/simultaneously extracted metals (AVS/SEM) laboratory analysis. All samples were immediately placed on ice for processing at the end of the day. Table 2-2 tabulates sediment sampling locations based on exposure areas and the corresponding analysis and includes surface soil samples collected in the corresponding oxbows and flood plains in each exposure area.

Table 2-2
Summary of Sediment Sampling

Location	Samples	Sampling Points	SVOCs, Metals, Cyanide, Mercury, and TOC	AVS/SEM
LSR-UP1	6	6	6	--
LSR-DWN1	6	6	6	--
LSR-DWN2	19	15	15	4
LSR-DWN3	12	11	11	1
LSR-DWN4	4	4	4	--
Total	47	42	42	5

The width of the stream was measured using a measuring tape in visually contaminated and downstream areas. The sediment depth was recorded based on the depth the sampling liner penetrated the sediment and also the depth of a steel rod. Once sampling was completed, the actual sampling location was recorded using a GPS by EPA FIELDS. Sampling personnel reached the locations by foot in areas too shallow to navigate by boat, such as ditches and upstream background locations (SD/SW-25 and SD/SW-26). In these locations a shovel was used because the water was shallow. In shallow areas, extra time was taken between water quality measurements and surface water sampling because sediments were disrupted. In all locations, stainless steel bowls and spoons were decontaminated prior to use at the next location.

2.1.2 Sediment and Soil from Low-Lying Areas

On October 28, 2010, SulTRAC with an EPA FIELDS member collected seven sediment and soil samples from low-lying areas near the LSR (see Figure 7). Areas sampled were selected based on accessibility and visual determination of previous flooding. There was no standing water at any of the locations; however, mud cracks or geographical settings indicated the presence of flooding. Samples were collected using a shovel and homogenized in a stainless steel bowl. Equipment was decontaminated between locations. Samples collected were immediately placed on ice and submitted for laboratory analysis of SVOCs, metals, cyanide, mercury, and TOC. Stainless steel bowls and spoons were decontaminated prior to use at the next location.

2.1.3 Fish and Invertebrate Sampling

On October 21, 25, and 26, 2010, SulTRAC with an EPA FIELDS member collected 50 fish samples (25 fillet and 25 carcass) from the LSR. SulTRAC obtained a permit to conduct the sampling from the Ohio DNR prior to field activities. The permit allowed SulTRAC to collect 50 fish samples but no sport fish larger than 6 inches. The methodology for obtaining fish samples was electro shock using a Smith-Root

1.5kVA Electrofisher mounted to the john boat. Fish samples were collected throughout the river but processed at locations shown on Figure 7. In general, most sampling began at a road crossing over the LSR and ended at a sampling point. Fish samples from one section were processed before moving onto the next section to segregate fish samples from each of the river sections (downstream, impacted, and remediated).

Fish samples were processed once a sufficient quantity was available at the GPS recorded location. Each sample was inspected and pertinent data were recorded on a field data sheet (see Appendix B for field data sheets). After they had been processed, samples were placed on ice for overnight shipping or same day delivery to the laboratory. Whole body fish samples were randomly selected for either a fillet or carcass sample. Fish samples were analyzed by a private laboratory for PAH, lipids, and target analyte list (TAL) metals. Ten samples were selected for target compound list (TCL) SVOCs from various locations. Table 2-3 summarizes fish sampling locations based on exposure areas in addition to the corresponding analysis.

Invertebrate samples were collected on November 2, 10, and 11, 2010 (see Figure 7). Samples were collected based on the presence of invertebrates in each of the river segments. No invertebrates were located in the remediated section; therefore, no samples were collected. The methodology for obtaining invertebrate samples consisted of wading in the river and using a shovel or looking bucket to determine the location of a mussel colony. Once found, the invertebrates were retrieved and processed on land. Pertinent information about the sample was recorded in the field logbook. The location of the sample was logged on a GPS. Samples collected were immediately placed on ice for overnight shipment to a private laboratory for TAL metals, lipids, and PAH analysis. Table 2-3 summarizes invertebrate sampling locations based on exposure areas in addition to the corresponding analysis.

Table 2-3
Summary of Fish and Invertebrate Sampling

Location	Type	Samples	Metals, Lipids, and PAHs	SVOCs
Fish Sampling				
LSR-UP1	Fillet	--	--	--
	Carcass	--	--	--
LSR-DWN1	Fillet	6	6	2
	Carcass	6	6	1
LSR-DWN2	Fillet	10	10	2
	Carcass	10	10	1
LSR-DWN3	Fillet	9	9	2
	Carcass	9	9	2
LSR-DWN4	Fillet	--	--	--
	Carcass	--	--	--
Total	--	50	50	10
Invertebrate Sampling				
LSR-UP1	Tissue	1	1	1
LSR-DWN1	Tissue	--	--	--
LSR-DWN2	Tissue	5	5	5
LSR-DWN3	Tissue	3	3	3
LSR-DWN4	Tissue	--	--	--
Total	--	9	9	9

2.1.4 Groundwater Investigation

From October 19 to 22, 2010, SulTRAC installed 20 temporary monitoring wells in four clusters adjacent to the LSR (see Figure 7). Soil borings were drilled to or past river sediment level using direct-push technology. Soil borings were drilled to the depth of the river level, at a minimum, to determine if contamination was visually present adjacent to the river. No soil samples were collected from the borings for chemical analysis. Once soil borings were complete, a temporary monitoring well with a 5-to 10-foot screen was installed in the borehole. The temporary monitoring well was finished with sand pack surrounding and 2 feet above the screen. A copy of the boring logs and temporary monitoring well completion forms is provided in Appendix C.

Groundwater samples were collected from each temporary monitoring well using a peristaltic pump and disposable tubing. Temporary monitoring wells that produced sufficient water were purged until groundwater quality parameters had stabilized and then sampled. The majority of the temporary monitoring wells did not produce sufficient water to conduct low-flow sampling; therefore, a grab sample was collected instead. Groundwater samples were submitted for laboratory analysis of TCL SVOCs and

TAL metals (plus cyanide). Table 2-4 summarizes groundwater sampling locations at each temporary monitoring well cluster and the corresponding analysis. Three of the four well clusters were located in exposure area LSR-DWN2 and the fourth cluster was located in exposure area LSR-DWN1.

Table 2-4
Summary of Groundwater Samples

Location	Locations/Samples	SVOCs, Metals, CN ⁻
Keener Road (LSR-DWN2)	5	5
Holland Road (LSR-DWN1)	5	5
State Route 95 (LSR-DWN2)	6	6
State Route 739 (LSR-DWN2)	4	4
Total	20	20

After the LSR RI had been completed, all temporary monitoring wells were abandoned. Each temporary monitoring well was abandoned by removing the riser and filling the hole with bentonite until reaching the ground surface. All temporary monitoring wells were abandoned on November 11, 2010.

2.1.5 Staff Gauge Investigation and Static Water Level Measurements

Staff gauges were installed in the LSR before field activities began. A staff gauge was installed near each temporary monitoring well cluster location in addition to an upstream (State Route 309) location and a downstream (Green Camp Road) location (see Figure 7). A professional surveyor measured the coordinates and elevation of the temporary monitoring wells and staff gauges after they were installed. The surface water elevations at each staff gauge were measured in conjunction with the groundwater elevations at temporary monitoring wells to evaluate the hydrogeologic relationship between shallow groundwater and the LSR.

2.2 BWC SUMMARY OF RI ACTIVITIES

On April 14, 2011, SulTRAC mobilized to the BWC site to conduct field sampling. Initial activities included gridding the entire BWC site, staking potential sampling locations, and collecting an initial round of water level readings from the existing permanent monitoring wells previously installed by EPA on the BWC site. The proposed grid locations were selected to provide overall coverage of the site while promoting more dense data collection in the former process area. The field investigation consisted of (1) conducting laser-induced fluoroscopy screening, (2) drilling soil borings and collecting soil samples, (3) installing temporary monitoring wells, (4) collecting groundwater samples, and (5) surveying all sampling locations. Each of these activities is discussed below.

The BWC planning document (SulTRAC 2010a) considered the BWC site to be one property; however, sample collection was emphasized on the eastern portion of the property, where the former processing area was located. Currently, the BWC property is owned by two different owners: the eastern portion of the site, encompassing approximately 25.9 acres, and consisting mostly of the former processing area; and the western portion of the site, encompassing approximately 34.1 acres, and consisting mostly of the former drying area. For purposes of the RI report, the BWC property was portioned into two exposure areas, which correspond to the exposure areas used for the risk assessments. The two exposure areas also correspond to the current owner property lines. The two exposure areas include the following:

- BWC-E: Eastern portion of the BWC property containing the former processing area
- BWC-W: Western portion of the BWC property containing the former drying area.

2.2.1 Laser-Induced Fluorescence Screening

During the week of April 18, 2011, SulTRAC subcontracted with Dakota Technologies, Inc. (Dakota), to use the Tar-specific Green Optical Screening Tool (TarGOST) at the BWC site. TarGOST is a laser-induced fluorescence (LIF) screening tool specifically designed to detect NAPL in the subsurface. It responds almost exclusively to NAPLs found at former manufactured gas plants and wood-treating (creosote and pentachlorophenol) sites. TarGOST is able to sense the fluorescence of PAHs and any other fluorescent molecules found in creosote light NAPLs (LNAPLs) and dense NAPLs (DNAPLs). The TarGOST system is a front-face fluorometer that is coupled via fiber optics to a sapphire-windowed probe that is advanced into the ground. The TarGOST system makes continuous measurements of the soil matrix as the windowed probe is pushed slowly into the subsurface. The light returning from the windowed probe is directed into a spectrometer located inside the TarGOST system, yielding a waveform. The spectrometer divides the light into four distinct wavelength bands and converts the light into a corresponding electrical current pulse where the current amplitude is proportional to the light amplitude. The current pulse is wired into a fast digital storage oscilloscope, where it is converted into a transient voltage signal, digitized, and recorded. The digitized transient is called a waveform.

The LIF soil borings were advanced by direct-push technology methods using a Geoprobe. One LIF boring was advanced within each grid and was advanced to bedrock (see Figure 8). The LIF investigation was conducted to determine if product was present at the BWC site, to assist in delineating the area of product, and to decide where soil borings and temporary groundwater monitoring wells should be installed. During the investigation, SulTRAC advanced a total of 71 LIF borings, which included one

duplicate boring location for comparison. If a location indicated the presence of product, SulTRAC stepped out from the original location to further delineate the extent of the product. Of the 71 LIF borings, 22 of the locations were advanced as step outs because product was present in the original boring location. Each LIF boring location was recorded using GPS. LIF screening logs are presented in Appendix D.

2.2.2 Soil Boring Activities

During the week of April 25, 2011, after the LIF screening was completed, soil borings were advanced at those locations that indicated the possibility of product or outside of the location to delineate the extent of product. Soil borings were advanced using direct-push technology methods and samples were obtained using MacroCore samplers and Lexan sleeves. Soil cores were continuously collected until bedrock was encountered or the probe met refusal. Once the sleeve was removed from the core rod, it was placed on the sampling table. A measuring tape was extended next to the core to measure the sample intervals and recovery. The soil was screened using a photoionization detector (PID), which was used to indicate the presence of VOCs and was used to help determine where a soil sample should be collected.

All soil borings were logged using geological logging forms, and the soil boring location was recorded using GPS. While each boring was advanced, the recorded interval, recovery amount, and PID readings were recorded. The PID was not operable because of the weather on some days of sampling. The lithologic description was also recorded for every interval and included a description of the soil type, including color, texture, and lithology in accordance with Unified Soil Classification System protocol. Soil boring logs are presented in Appendix E.

A total of 35 initial soil borings were advanced throughout the BWC site. Sampling locations from the April 2011 investigation are presented on Figure 9. A total of two samples were collected from each boring at two different depth intervals. At each soil boring location, SulTRAC collected a soil sample from the 0- to 2-foot interval. The second sample was collected from the depth interval that exhibited the highest contamination based on the LIF screening. If the boring location did not exhibit product during the LIF screening, SulTRAC based the collection depth of the second sample on field observations such as visible discoloration of soils or the presence of odors and PID screening results. In some boring locations, SulTRAC did not observe any unusual field observations or elevated PID results and, therefore, the second sample was collected from the 8- to 10-foot interval. This depth was presented in the SulTRAC sampling and analysis plan (SAP) approved by the EPA and Ohio EPA.

A total of 70 soil samples, not including duplicate samples, were collected. The soil samples were sent to a subcontracted laboratory for analysis of TCL VOCs, TCL SVOCs, and TAL metals. SulTRAC collected samples for analysis of VOCs first, followed by SVOCs and then metals.

2.2.3 Groundwater Activities

During the week of April 25, 2011, SulTRAC installed temporary monitoring wells at 18 of the 35 soil boring locations drilled at the BWC site. Figure 9 presents the temporary monitoring well locations. The temporary monitoring wells were installed to evaluate whether shallow groundwater beneath the BWC site is contaminated and has the potential to affect the LSR. The target depth of the temporary monitoring wells was the interface between the unconsolidated material and the bedrock, which was encountered between 11 and 18 feet bgs, depending on the particular location.

A temporary monitoring well was installed at a soil boring location if field personnel observed visible contamination or elevated PID readings. If contamination or elevated PID readings were not observed, temporary monitoring wells were installed at select locations that provided a potential clean perimeter to assist in delineating the extent of contamination. The temporary monitoring well locations were recorded with GPS.

After review of the soil boring, the well screen interval was chosen and the temporary monitoring well was installed. Each temporary monitoring well was screened in a shallow water-bearing unit identified during advancement of the soil boring. Each temporary monitoring well was constructed using 2-inch-diameter polyvinyl chloride (PVC) with a 5-foot screen with 0.020-inch slot size. The depth to bottom of each temporary well was measured from the top of the well casing to verify completion depth.

Each temporary monitoring well was installed with a #5 silica sand filter pack that extended 1 foot above the screen. The remaining annular seal space was filled with a high-solids, all-bentonite grout. The PVC riser was completed about 2 to 3 feet above grade and capped. Temporary monitoring wells were not developed. Temporary monitoring well logs are presented in Appendix E.

After the temporary monitoring wells had been installed, groundwater samples were collected using low-flow techniques to minimize increased colloid mobilization by removing water from the well at the screened interval at a rate that preserved or minimally disrupted steady-state flow conditions in the

aquifer. A peristaltic pump was used to pump water from the temporary well. The tubing intake was placed in the saturated portion of the formation, approximately 2 to 3 feet above the bottom of the well screen. Readings of field parameters were collected at 3- to 5-minute intervals. The well water was considered stabilized after three successive measurements of field parameters at 3- to 5-minute intervals that fell within the following ranges: ± 0.1 for pH, $\pm 3\%$ for conductivity, ± 10 millivolts for oxidation reduction potential (ORP), and $\pm 10\%$ for turbidity (greater than 10 nephelometric turbidity units [NTU]) and dissolved oxygen. During low-flow sampling, field parameters were measured using a flow-through cell. Because the temporary wells were not developed, turbidity did not always meet its stabilization requirement. In these instances, SulTRAC calculated the well volume and purged three well volumes from the well before the sample was collected. Appendix F presents the field parameter logs for all temporary monitoring wells installed at the BWC site.

SulTRAC recorded the following information at each temporary monitoring well groundwater sampling location: date and time, temperature and general weather conditions, and depth to water measured from the top of the well casing. The same equipment used to stabilize the temporary monitoring well was used to sample each well; however, disposable tubing was used at each well and was discarded before the field team moved to the next sampling location. The water level meter was decontaminated after sampling was completed at each temporary monitoring well. Groundwater samples were collected at each location for analysis for VOCs first, followed by SVOCs, and then total (unfiltered) TAL metals, including cyanide. Samples were poured directly into the appropriate (glass or high-density polyethylene) containers. Samples were immediately placed in iced coolers and maintained at a temperature of $4 \pm 2^\circ\text{C}$ without freezing until they were delivered to the laboratory under standard chain-of-custody protocol.

Groundwater samples were submitted to the subcontracted laboratory for analysis of TCL VOCs, TCL SVOCs, and TAL metals (plus cyanide).

During the week of April 25, 2011, SulTRAC also collected groundwater samples from the nine existing permanent monitoring wells previously installed on the BWC site. Figure 9 presents the permanent monitoring well locations at the BWC site. The permanent monitoring well locations were recorded with GPS.

The permanent monitoring wells were stabilized and sampled in the same manner as the temporary monitoring wells. Groundwater samples collected from each permanent monitoring well were sent to a subcontracted laboratory for analysis of TCL VOCs, TCL SVOCs, and TAL metals.

During the initial groundwater investigation, SulTRAC collected a complete round of water level measurements from all temporary and permanent monitoring wells. Water levels at temporary and permanent monitoring wells were measured from the north side of each well for consistency. Appendix G presents water level measurements from the April 2011 sampling event.

2.2.4 Surveying Activities

During the week of August 2, 2011, SulTRAC returned to the BWC site to survey all temporary and permanent monitoring wells. Each well was surveyed for ground surface elevation, top of casing elevation, and horizontal location by a licensed surveyor. The temporary and permanent monitoring well locations were also recorded with GPS by the licensed surveyor. Survey results are included in Appendix H.

2.2.5 Additional Activities

The following sections describe additional activities or sampling conducted at the BWC site to support the RI. Additional sampling was conducted in April, August, and November 2011, and February 2012. Additional sampling activities are discussed below.

April 2011

In April 2011, SulTRAC collected one waste sample from the slag pile that remains on the BWC site (see Figure 9). SulTRAC collected waste material from five areas of the pile and composited the material into one sample. A disposable pan and spoon were used to homogenize the sample. The sample was sent to a subcontracted laboratory for analysis of toxicity characteristic leaching procedure (TCLP) VOCs, TCLP SVOCs, TCLP Resource Conservation and Recovery Act (RCRA) metals, TCL VOCs, TCL SVOCs, and TAL metals.

SulTRAC also collected one surface soil sample from the soils surrounding the slag pile (see Figure 9). SulTRAC collected surface soil from five areas around the base of the slag pile and composited the soil into one sample. A disposable pan and spoon were used to homogenize the sample. The soil sample was

sent to a subcontracted laboratory for analysis of TCLP VOCs, TCLP SVOCs, TCLP RCRA metals, TCL VOCs, TCL SVOCs, and TAL metals.

August 2011

During the week of August 2, 2011, SulTRAC collected another round of water levels from all temporary and permanent monitoring wells at the BWC site. SulTRAC used a water/oil interface probe to detect the presence or absence of LNAPL or DNAPL in each well. Water levels were measured from the north side of the well casing as in the previous investigation. SulTRAC did not detect DNAPL in any of the wells; however, because of the nature of the temporary monitoring wells, it would have been difficult to detect small amounts of DNAPL at the bottom of the well, if present.

November 2011

During the week of November 28, 2011, SulTRAC returned to the BWC site to install additional temporary monitoring wells, collect additional soil samples, and collect another round of water level measurements. Figure 10 shows all temporary well locations and soil sample locations installed or sampled during the November 2011 investigation. Water level measurements are presented in Appendix G, and survey information for these three temporary monitoring wells is included in Appendix H.

SulTRAC installed three additional temporary monitoring wells to help further define the extent of groundwater contamination at the BWC site (see Figure 10). SulTRAC installed one well along the southern boundary of the site, west of existing temporary well BWC-07A; installed another temporary well in between existing temporary well BWC-07A and BWC-23; and installed the third temporary well just outside the east side of the bioremediation area. Temporary wells were installed, stabilized, and sampled in the same manner as during the April 2011 investigation. Groundwater samples were collected from all three wells and analyzed by a subcontracted laboratory for TCL VOCs, TCL SVOCs, and TAL metals.

All soil samples collected during the initial investigation were analyzed for TAL metals. SulTRAC collected a total of eight additional soil samples for chromium speciation to determine if hexavalent chromium existed at the BWC site. Soil samples were collected at previous soil boring locations and were collected from shallow and deep intervals. Soil samples were analyzed by a subcontracted laboratory for hexavalent and total chromium.

SulTRAC also collected another round of water level measurements from all temporary monitoring wells, including the three new temporary wells installed, and the permanent wells.

February 2012

SulTRAC mobilized to the BWC site in February 2012 to install four additional temporary monitoring wells along the northern border of the BWC site, collect additional soil samples in the former drying area, and collect another round of water level measurements. Figure 11 presents the location of the temporary monitoring wells and soil samples. Water level measurements are presented in Appendix G, and temporary monitoring well survey information is presented in Appendix H.

SulTRAC installed four additional temporary monitoring wells along the northern border of the BWC site to serve as background groundwater sampling locations (see Figure 11). Temporary monitoring wells were installed, stabilized, and sampled in the same manner as during previous sampling events.

Groundwater samples were analyzed by a subcontracted laboratory for TCL VOCs, TCL SVOCs, and TAL metals. Temporary monitoring well logs are presented in Appendix E.

SulTRAC also collected soil samples from 38 previously screened or sampled soil boring locations at the BWC site. Figure 11 presents the soil sampling locations. The soil samples were collected to gather additional data for the human health and ecological risk assessments for the BWC site. Soil samples were either collected from (1) previously sampled locations from an additional depth interval closer to the ground surface for human health and ecological risk assessment purposes, or (2) from LIF screening locations that were not sampled because they did not indicate the presence of product but still might present contamination at the ground surface. SulTRAC collected one sample for risk assessment at locations that had been previously sampled. This sample was collected at a 2-foot interval between 2 and 10 feet bgs to take into consideration the depth interval appropriate for human health risk assessment. SulTRAC followed original procedures outlined in the EPA-approved SAP where a total of two samples were collected at two depths (0- to 2-feet bgs and a second interval selected by field observations) at locations where only LIF screening had occurred. However, the deeper sample was collected at a depth above 10 feet bgs to provide data that could be used for risk assessment. The majority of the samples were collected from the eastern property border and the former drying area on the western part of the site where LIF screening did not indicate the presence of product. A total of 67 soil samples were collected and analyzed by a subcontracted laboratory for TCL VOCs, TCL SVOCs, and TAL metals.

Based on historical data, SulTRAC also collected soil samples to evaluate whether pesticide contamination is present in the former processing area. SulTRAC collected soil samples from eight locations within and around the former processing areas (see Figure 11). Soil borings were advanced using direct-push technology methods. Two soil samples were collected from each boring location; one sample from each boring was collected from 0 to 2 feet bgs; the second sample was collected from a depth less than 7 feet bgs. If stained soils were observed, the sample was collected from that interval; if no stained soils were observed, the sample was collected at varying depths between 2 and 7 feet bgs. A total of 16 soil samples from eight sampling locations were analyzed by a subcontracted laboratory for pesticides.

SulTRAC also collected a round of water level measurements from all temporary monitoring wells, including those installed during this event, and all permanent monitoring wells. Water level measurements are presented in Appendix G.

Figure 12 presents all sampling locations at the BWC site from all four investigations conducted between April 2011 and February 2012.

3.0 PHYSICAL CHARACTERISTICS OF THE LSR AND BWC SITES

The following sections present the general physical characteristics of the LSR and BWC sites, including the general setting, demographics and land use, geology, hydrogeology, and ecological habitat of both sites.

3.1 GENERAL SETTING

This section describes the regional setting of Marion County and its typical climate, the LSR site setting, and the BWC site setting. Each of these is discussed below.

3.1.1 Regional Setting

Marion County occupies approximately 404 square miles in north-central Ohio. Marion County is bounded to the north by Wyandot County and Crawford County, to the east by Morrow County, to the south by Delaware County, to the west by Union County and Hardin County. Weatherbase.com (Weatherbase 2012) reports an average annual temperature of approximately 50 degrees Fahrenheit for the City of Marion. The website also states that the precipitation averages about 33.2 inches per year for the city. The mean annual precipitation for Marion is 38.5 inches per year based on a 30-year (1971-2000) period.

3.1.2 LSR Setting

The Scioto River basin is approximately 6,510 square miles in size and includes more than 4,000 miles of rivers and streams. It stretches from just inside Auglaize County to the Ohio River at Portsmouth in Scioto County. The LSR begins in Crawford County and flows into the Scioto River at Green Camp, Ohio, draining 113 square miles (Ohio EPA 2008). The LSR flows north to south and feeds the Scioto River, a major tributary to the Ohio River. The river channel is mostly vegetated with trees and overgrown brush on the banks or borders agricultural fields. The LSR site area is approximately 8.5 river miles, including 1.5 miles of NRD, 2.2 miles of Rockswale Ditch, 1.1 miles of Columbia Ditch, 1.4 miles of Unnamed Ditch, and various sized former oxbow lakes and low-lying areas adjacent to the present river channel.

NRD is located at the northern portion of the site and flows south until it reaches Holland Road, where it then flows west for approximately 0.5 miles before it converges with the LSR. Rockswale Ditch is located south of Holland Road and does not appear to be connected to NRD. Columbia Ditch is located east of the

LSR and Rockswale Ditch and flows west southwest into Rockswale Ditch, which then trends southwest until it reaches the LSR. The ditches are all approximately 1 foot or less deep in most areas and could not be navigated by boat. The Unnamed Ditch was included as part of the field investigation; however, it could not be located. The area where the Unnamed Ditch was previously located is now in an overgrown agricultural field.

Former oxbow lakes and low-lying areas are present throughout the site and located adjacent to the LSR. Locations chosen to be part of the investigation area were based on (1) evidence that the area is hydrologically connected to the LSR such as oxbow topography, mud-cracks, or standing water lines, (2) obtaining access agreements, and (3) physical site access. No areas were flooded during the investigation. Site conditions surrounding the oxbow lakes and low-lying areas matched the general site conditions of areas surrounding the LSR.

Figure 2 presents the interactions between the various watersheds in and along the LSR. The LSR investigation area begins at the State Route 309 Bridge and extends to the confluence with the Scioto River just south of Green Camp, Ohio.

3.1.3 BWC Setting

The BWC site occupies about 60 acres of historically industrial and wooded areas. The western portion of the site is the predominantly wooded area. It operated as a lumber preserver from the 1890s until the 1960s. Lumber, including railroad ties, was preserved with coal tar creosote, petroleum, and other solvents in pressurized tanks. The lumber was then stacked to dry on the western portion of the BWC property. Former railroad lines can be found throughout the BWC site. The area formerly referred to as the railroad tie yard or drip yard, where raw and finished wood products were stored, covered the majority of the site's western portion and has become overgrown with dense woodland.

Evidence of the old creosoting operation still exists. The foundations of many of the old buildings are still evident, and one metal building still exists in the northeastern part of the site. Only a portion of the site is secured with fencing, erected during EPA removal activities. The site is within an area subject to minimal flooding, but is not in a flood zone (Ohio EPA 2003).

3.2 DEMOGRAPHICS AND LAND USE

This section describes the regional demographics and land use as well as land use specific to the LSR BWC sites. Each of these is discussed below.

3.2.1 Regional Demographics and Land Use

The approximate population of Marion County, based on the 2010 census is 66,501 (U.S. Census Bureau 2010). Agriculture accounts for roughly 86 percent of the land usage in Marion County. Row crops are the primary agricultural land usage. Woodlands, industry, and residential are the other major land uses in the county. The City of Marion is the largest community and the county seat. The approximate population of the City of Marion, based on the 2010 census, is 36,837.

The municipal water supply for the City of Marion serves a population of approximately 48,000 and is primarily from the Scioto and Little Scioto Rivers (Ohio EPA 2003). Twenty to 30 percent of the water is from 16 groundwater wells and is blended with the surface water to balance high turbidity. The groundwater supply wells are located at the wellfield west of the BWC site, just west of the LSR. The supply wells are cased from the surface to approximately 45 to 60 feet bgs and are open in the limestone bedrock at depths ranging from 180 to 450 feet bgs. At least three of Marion's supply wells are located on the east side of the LSR; the easternmost of which is within 0.5 mile of the BWC site's western edge. Depth to water, as noted in well logs, is at approximately 20 to 45 feet bgs. The water elevation in the supply wells is higher than the bedrock surface elevation and overlying sand and gravel elevation, indicating that the bedrock aquifer is confined by the overlying clay.

Two surface water intakes are used to blend with groundwater (Ohio EPA 2003). The Scioto River intake is located approximately 4.3 miles southwest of the site and is situated upstream of Green Camp, where the confluence of the LSR and Scioto River is located. The LSR intake is approximately 1.5 miles northwest of the site, 0.8 mile upstream of Holland Road and the probable point of entry of site contamination to the LSR.

According to the Marion County Farm Service Agency, neither groundwater nor surface water in the area of the LSR or Scioto River is used as an agricultural resource (Ohio EPA 2008).

Land use relative to the LSR and BWC sites is discussed below.

3.2.2 LSR Land Use

The LSR site is located just west of the City of Marion and west of the BWC site. The LSR is located in a primarily low-density residential area with unrestricted access via agricultural fields, bridges, state-designated recreation areas, and wildlife areas. The LSR does not appear to serve as a recreation area that supports significant swimming or fishing based on site observations. The LSR is currently under a fish consumption advisory for all species of fish because of the PAH contamination in areas located from Holland Road to State Route 739 (Ohio EPA 2012).

3.2.3 BWC Land Use

The BWC site is located west of the City of Marion. The site is bounded to the north and west by agricultural fields, to the east by Harding Highway and low-density residential properties, and to the south by Holland Road then Union Tank Car and a Whirlpool shipping facility. The site is currently vacant with no on-site workers. The general land use within 1 mile of the site is residential and commercial to the north and east, industrial to the south, and agricultural to the west (Ohio EPA 2003).

3.3 SITE GEOLOGY

This section presents the regional geology for the Marion County area (Ohio EPA 2008) followed by site geology characterized during the LSR and BWC investigations. Regional and site-specific geology is discussed below.

3.3.1 Regional Geology

The topography for Marion County was evaluated using U.S. Geological Survey (USGS) 7-1/2 minute quadrangle maps and the Soil Survey of Marion County (Miller and Martin, 1989). Slopes of 0 to 2 percent were identified for almost all of the settings in Marion County based on the overall flat-lying to gently rolling topography and low relief. Slopes of 2 to 6 percent were assigned to most end moraines exhibiting hummocky terrain. Slopes of 6 to 12 percent were selected for a limited number of areas where the Scioto River or Olentangy River have steeply downcut the surrounding end moraine or ground moraine in southern Marion County.

The glacial deposits in Marion County are the result of several episodes of ice advance that occurred in northwestern Ohio. The majority of the glacial deposits in Marion County fall into four main types: (glacial) till, outwash (valley train) deposits, and ice-contact sand and gravel (kames and eskers) deposits, and lacustrine deposits (ODNR 2003). Each of these types of glacial deposits is discussed below.

Till is an unsorted, non-stratified (non-bedded), mixture of sand, gravel, silt, and clay deposited directly by the ice sheet. There is evidence that some of the Marion County tills were deposited in a water-rich environment and may more closely resemble lacustrine deposits (ODNR 2003). Till has relatively low inherent permeability. Permeability in till depends in part on the primary porosity of the till, which reflects how fine-textured is the particular till. Vertical permeability in till is controlled largely by factors influencing the secondary porosity such as fractures (joints), worm burrows, root channels, and sand seams. End moraines present in Marion County are composed of a high proportion of sand and gravel units interbedded in the till, which may increase its permeability (ODNR 2003).

Till accounts for two primary landforms at the land surface: ground moraine and end moraine. Ground moraine is relatively flat to gently rolling. End moraines are ridge-like, with terrain that is steeper and more rolling or hummocky. End moraines commonly serve as a local drainage divide because of their ridge-like nature. The St. Johns Moraine roughly parallels the southern margin of the Scioto River through Bowling Green Township and Green Camp Township and then trends northeastward toward the City of Marion. A segment or portion of the St. Johns Moraine is also evident in Scott Township. The Wabash Moraine roughly follows the northern margin of the Scioto River in Montgomery Township and Big Island Township and the western margin of the LSR in Marion Township and Grand Prairie Township (ODNR 2003).

Outwash deposits are generally bedded or stratified and sorted materials created by active deposition of sediments by meltwater streams. Outwash deposits in Marion County are mostly associated with the Scioto River near La Rue and also between Green Camp and Prospect. The outwash deposits in Marion County tend to have a significant proportion of relatively fine-grained sand and silt layers. The outwash deposits flanking the Scioto River are finer-grained than those found farther south in Franklin County. This finer-grained nature would seem to indicate that the sediments were deposited by relatively slow-moving meltwater (ODNR 2003).

Kames and eskers are ice contact features. They are composed of masses of generally poorly sorted sand and gravel with minor till, deposited in depressions, holes, tunnels, or other cavities in the ice. As the surrounding ice melts, a mound of sediment remains behind. The best examples of ice contact deposits are kames found along the Scioto River between Prospect and Green Camp and kame terraces flanking Ququa Creek northwest of Waldo (ODNR 2003). Marion County also contains abundant kettles (ODNR 2003). Melting blocks of ice formed small circular depressional features called kettles. Kettles are usually

associated with areas of ablation where the ice sheet was actively melting. As the ice block melted, it left behind a hole or low area surrounded by either till or outwash.

Deposits formed by lakes created during recession of ice sheets are called lacustrine deposits and consist of silty to clayey material. These lakes are referred to as intermorainal lakes as they occupy low areas of ground moraine between end moraines. Lacustrine deposits tend to be laminated (or varved) and contain various proportions of silts and clays. Permeability is preferentially horizontal because of the laminations and water-laid nature of these sediments. The inherent vertical permeability is slow; however, secondary porosity features such as fractures, joints, and root channels help increase the vertical permeability (ODNR 2003). Glacial Lake Marion occupies the low area between the Wabash Moraine and the St. Johns Moraine. The Scioto River cuts through the former lakebed (ODNR 2003).

Bedrock underlying the surface of Marion County belongs to the Silurian, Devonian, and Mississippian Systems. Carbonate (limestone and dolomite) bedrock underlies the western and central portions of Marion County. Based on a state geological map, the bedrock in Marion appears to be of Devonian age. A review of the well logs in the vicinity of the area compiled by the Ohio EPA indicates that the geology of Marion County consists primarily of fractured limestone deposits with a thin, clayey overburden (Ohio EPA 2008). The well logs also indicate bedrock within a 4-mile radius ranging from 14 feet bgs to 57 feet bgs. The depth to bedrock ranges from approximately 5 feet near the former BWC site to greater than 80 feet 3 miles west of the site.

3.3.2 LSR Geology

The LSR is a low-velocity, high-turbidity river that ranges between 30 and 45 feet wide and 6 inches to more than 5 feet deep in pooled areas. The streambed consists primarily of sand with clay/silt fractions in certain areas. The topography of the LSR site area is generally flat (slopes of 0 to 2 percent) with a slight decline toward the LSR.

Table 3-1 below provides a summary of information collected about the LSR and connecting waterways during the investigation. During the investigation, SulTRAC did transects along the LSR and connecting waterways to determine the width of the river as well as the depth of sediment present.

**Table 3-1
LSR River Width and Sediment Thickness**

Transect	River Width (feet)	Sediment Depth (inches)			
		Western Point	Center Point	Eastern Point	Maximum Depth
LSR-SD01	NM	18	24	18	24
LSR-SD02	42.5	12	16	12	16
LSR-SD03	38	30	7.5	24	31
LSR-SD04	38	30	36	30	36
LSR-SD05	38.5	30	36	30	52
LSR-SD06	35.6	19	24	19	75
LSR-SD07	34	17	20	14	36
LSR-SD08	34.5	6	7	7	27
LSR-SD09	38	36	36	24	48
LSR-SD10	32	24	20	12	36
LSR-SD11	41.1	24	6	30	42
LSR-SD12	42.5	5.5	6	4.5	6
LSR-SD13	35.5	33	36	36	84
LSR-SD14	NM	79	36	36	79
LSR-SD15	43.5	45	42	30	45
LSR-SD16	39.5	45	48	39	48
LSR-SD17	35	24	18	54	54
LSR-SD18	33.5	66	48	12	66
LSR-SD19	36	48	48	48	48
LSR-SD20	44.5	NA	2	NA	2
LSR-SD21	39.3	NA	9	NA	9
LSR-SD22	41.5	NA	18	NA	18
LSR-SD23	41	NA	12	NA	12
LSR-SD24	31.5	NA	24	NA	24
LSR-SD25	35	NA	8	NA	8
LSR-SD26	37	NA	12	NA	12

Other Connecting Waterways

Transect	River Width (feet)	Sediment Depth (inches)			
		Transect Point 1	Transect Point 2	Transect Point 3	Maximum Depth
NRD-01	12.5	6 (N)	6 (C)	6 (S)	6
NRD-02	14	6 (N)	6 (C)	6 (S)	6
NRD-03	12	6 (W)	6 (C)	6 (E)	6
NRD-04	8.5	6 (W)	6 (C)	6 (E)	6
NRD-05	NM	6 (W)	6 (C)	6 (E)	6
RD-01	18	6 (N)	8 (C)	6 (S)	8
RD-02	8	6 (W)	6 (C)	6 (E)	6
RD-03	15	6 (W)	6 (C)	6 (E)	6
CD-01	12.5	6 (N)	6 (C)	4 (S)	6

Notes:

LSR = Little Scioto River
NRD = North Rockswale Ditch
RD = Rockswale Ditch
CD = Columbia Ditch

NM = Not measured
W = West
N = North
S = South
C = Center

NA = Not applicable

Transects were located in the areas of the LSR where contamination had previously been observed down to the confluence with the Scioto River. Transects were not used in the remediated and upgradient areas because it was assumed that material would not require removal. In the remediated and upgradient areas, the width of the river was recorded and one sediment depth was recorded from the center of the river or connecting waterway. In the remainder of the river and other connecting waterways, the river width was recorded and the sediment depth was recorded for three locations along the transect (north/center/south or west/center/east, depending on the orientation of that portion of the waterway). At each point along a given transect, sediment depth was measured using a coring device during sample collection. In some portions of the river, a rod with a tape measure was also used to obtain a maximum depth of sediment. This maximum depth was measured at only the center point within a transect location and is recorded in Table 3-1. If the rod was not used, the maximum depth presented in the table represents the maximum depth of sediment at one of the three transect locations based on the coring device.

Based on the investigation, sediment thickness within the LSR ranged from 2- to 84-inches thick. Sediment thickness within the connecting waterways ranged from 4- to 8-inches thick.

Surficial geology immediately surrounding the Little Scioto River, based on the United States Department of Agriculture (USDA) Web Soil Survey (USDA 2012), changes throughout the extent of the study area. From County Highway 94 going south to Holland Road, the soil type surrounding LSR is a Saranac silty clay loam that is occasionally flooded. A typical Saranac vertical profile is a silty clay loam to 17 inches and silty clay from 17 inches to 60 inches. From Holland Road to State Highway 95, soil is classified as udorthents. This segment contains the area where a landfill is located. From State Highway 95 to State Highway 739, soil is classified as Saranac or a silty clay loam that is frequently flooded. From State Highway 739 to the confluence of the Scioto River and LSR, the soil is a Sloan silty clay loam that is occasionally flooded. A typical vertical profile of a Sloan silty clay loam is silty clay loam to 11 inches, clay loam from 11 to 47 inches, and stratified gravelly sand loam to silty clay loam to 60 inches. Soil characteristics for connected ditches tend to match the profile of the LSR for the corresponding segments.

Bedrock was not encountered during the groundwater investigation along the LSR. Borings were advanced between 20 and 40 feet bgs. Soil borings were advanced in four general locations along the LSR. Keener Road soil borings encountered predominantly silty clay to below 30 feet bgs with infrequent sand and silt layers. In general, soil borings at Holland Road encountered silt and silty clay to around 20 feet bgs and then alternating sand and clay layers. Soil borings at State Route 95 encountered silt or silty

clay to below 30 feet bgs. At State Route 739, soil borings encountered silt and sand sometimes in alternating layers to deeper than 30 feet bgs. Detailed logs of soil borings drilled at each location are provided in Appendix C.

3.3.3 BWC Geology

Surficial geology at the BWC site, based on USDA Web Soil Survey (USDA 2012), consists of Pewamo-Urban land complex and Blount-Urban land complex. A typical profile for the Pewamo-Urban land complex is a silty clay loam to 53 inches and a clay loam from 53 inches to 60 inches. A typical profile for the Blount-Urban land complex is a silt loam to 10 inches and clay loam from 10 to 60 inches.

Surficial soils at the BWC site have been disturbed and reworked by past operations, previous removal actions conducted by EPA, and construction and dismantling of the bioremediation are used during the LSR removal action. In addition, a slag pile is present east of the former bioremediation area, and slag is present throughout the site at or near the ground surface.

Unconsolidated materials encountered during drilling at the BWC site included several distinct types of materials with a total thickness ranging from about 10 to 20 feet. Soil boring logs for BWC are presented in Appendix E. Figure 13 shows the locations of the cross-sections at the BWC site. The representative geologic cross sections are shown in Figures 14 through 20.

As shown in the cross sections, the uppermost unconsolidated materials encountered during drilling generally consist of topsoil, sand, gravel, slag, or a combination of these. These materials are underlain by slag, fill, or in some places black silty clay. The fill material is typically underlain by brown mottled silty clay, sometimes containing small amounts of sand and gravel. The brown silty clay is typically underlain by gray stiff to soft silty clay containing varying amounts of sand and gravel. The gray silty clay is typically underlain by weathered, fractured limestone bedrock. Sand is present between the brown and gray silty clays at some locations and sand and gravel were present between the gray silty clay and the limestone bedrock at some locations.

The depth to bedrock at the BWC site ranges from about 10 feet bgs to about 20 feet bgs based on probe refusal or bedrock encountered in the actual sampling device during the soil and groundwater investigation. In general, bedrock slopes downward from east to west. The elevation changes about 13 feet from the easternmost boring (BWC-01, elevation 921.2 msl) to the westernmost boring (BWC-46, elevation 907.98 msl). However, the bedrock surface is not smooth and contains localized high areas and

depressions. Figure 21 presents a map showing the top of bedrock surface at the BWC site. The bedrock was not significantly penetrated at any of the boring locations during the RI; therefore, information on deeper bedrock is available at only the deep monitoring well locations installed by EPA. Information from the EPA well logs suggests that the limestone becomes more competent with depth.

3.4 SITE HYDROLOGY

This section presents the regional hydrogeology for the Marion County area, followed by site hydrogeology characterized during the LSR and BWC investigations. Regional and site-specific geology is discussed below.

3.4.1 Regional Hydrogeology

Marion County lies entirely within the Glaciated Central hydrogeologic setting. Limestones and dolomites of the Silurian and Devonian Systems compose the aquifer in the western and central portions of the county. Yields in the uppermost carbonate aquifers range from 5 gallons to 100 gallons per minute (gpm). Yields larger than 100 gpm are possible from larger-diameter wells drilled deeper into limestone (Ohio EPA 2008). Regional groundwater flow in the bedrock aquifer is most likely influenced by quarry operations northeast of the site and by the municipal wellfield west of the site (Ohio EPA 2003). When pumping does not occur at the quarry to the northeast, groundwater flow will be primarily influenced by the pumping wellfield to the west. Other factors that influence groundwater flow in this region are surface water bodies and hydraulic gradient. Typically, however, groundwater flows westward in the direction of the LSR.

3.4.2 LSR Hydrogeology

Surface water run-off drains to the west into the Little Scioto River, which flows south and connects to the Scioto River at Green Camp about 3 miles to the south. Smaller north-south running ditches are also near the site and drain to the Little Scioto River. One of these, Rockswale Ditch, appears to have cut across the Union Tank Car site in the past; however, its northern branch appears to have been truncated just south of Holland Road and rerouted to flow west to the Little Scioto River.

Temporary monitoring wells were installed in four clusters along the Little Scioto River to determine the direction of groundwater flow relative to the LSR. A staff gauge was installed in the LSR at each temporary monitoring location, and at an upstream (Highway 309) and downstream (Green Camp Road) location. Temporary monitoring wells and staff gauges were surveyed to establish measurement reference

points. Water levels were gauged a total of three times at all temporary monitoring well and staff gauge locations to provide a snapshot of hydrologic conditions and to assess the relationship between river elevations and groundwater elevations in the temporary wells. Frequency of water gauging was once a week and all locations were gauged within a 24-hour period.

Over the course of the 3-week gauging period, static water level in temporary monitoring wells appears to be relatively stable, generally varying within about 0.5 foot between measurement events, with the exception of TW-11 and TW-12 that were installed in a clay or silty clay medium (see Table 3-2). Water levels at these two locations varied by as much as 7.1 feet at TW-11 and 2.18 feet at TW-12. In addition, over the same gauging period, the river elevation varied by less than 0.3 foot between gauging events and the river elevation dropped between 4 and 5 feet (depending on the measurement event) from the farthest upstream staff gauge (Highway 309) to the farthest downstream staff gauge (Green Camp Road).

Water levels measured at each staff gauge and each corresponding cluster of temporary monitoring wells varied less than one-tenth and up to four-tenths of a foot at the upstream location at State Route 309. The relationship between the groundwater and the LSR appears to vary based on location. At Keener Pike and Holland Road, the LSR appears to be losing, while at State Route 95 and State Route 739, the LSR appears to be gaining. It should also be noted that measurements were made over a 3-week period in the fall, and seasonal patterns influenced by precipitation events could result in periodic changes in the relationship between surface water and groundwater elevations.

Table 3-2
Temporary Well and Staff Gauge Locations

Station ID	Top Elevation	Screen Depth	Water Elevation 10/24/2010	Water Elevation 11/2/2010	Water Elevation 11/9/2010
<i>Keener Pike (mean sea level)</i>					
TW-01	908.06	15-20'	895.65	896.06	896.39
TW-02	909.42	27-32'	896.99	896.57	896.50
TW-03	906.33	10-15'	899.60	898.54	899.50
TW-04	906.25	10-15'	896.60	896.77	896.87
TW-05	906.97	15-25'	897.43	897.57	897.52
Staff Gauge	902.08	--	899.60	Not collected	899.68
<i>Holland Road (mean sea level)</i>					
TW-06	914.14	28-33'	891.72	891.43	891.24
TW-07	914.10	27-32'	891.49	891.12	891.04
TW-08	912.77	26-31'	891.37	890.94	890.91
TW-09	912.00	25-30'	891.85	892.55	891.39
TW-10	911.79	24-29'	891.83	891.59	891.39
Staff Gauge	903.83	--	901.78	901.83	901.84
<i>State Route 95 (mean sea level)</i>					
TW-11	916.80	26-31'	913.72	906.62	907.12
TW-12	912.75	24-29'	905.33	907.04	907.51
TW-13	907.90	27-32'	902.40	902.57	902.63
TW-14	909.74	22-27'	902.94	902.95	903.02
TW-15D	909.60	21.2-26.2'	902.80	902.86	902.94
TW-15S	908.19	11-16'	904.54	904.68	904.71
Staff Gauge	904.04	--	901.73	901.82	901.76
<i>State Route 739 (mean sea level)</i>					
TW-16	905.01	16-21'	898.30	898.16	898.24
TW-17	906.06	16.11-21.11'	898.29	898.27	898.26
TW-18	904.62	10-20'	898.31	898.31	898.29
TW-19	903.83	15-20'	898.35	898.33	898.34
Staff Gauge	899.70	--	897.35	897.40	897.41
<i>Green Camp Road (mean sea level)</i>					
Staff Gauge	900.69	--	898.08	898.11	898.10
<i>State Route 309 (mean sea level)</i>					
Staff Gauge	904.59	--	902.43	902.82	902.69

3.4.3 BWC Hydrogeology

Two water-bearing zones were investigated as part of the RI. Groundwater present in the unconsolidated sands and in the weathered bedrock at the interface of the unconsolidated sands and bedrock is referred to as shallow groundwater. Groundwater present in the fractured competent limestone bedrock is referred to as deep groundwater. Temporary monitoring wells were installed in the unconsolidated material at 25 soil boring locations after soil sampling to aid in assessing shallow hydrological conditions. In general, temporary monitoring wells were installed at the furthest extent of probe advancement or in a hydrologically conductive zone (sand and gravel) where groundwater could be visually confirmed. An

additional five existing permanent monitoring wells were also used as part of the shallow groundwater monitoring network and four existing permanent monitoring wells were used as the deep (bedrock) groundwater monitoring network.

LNAPL was measured in temporary wells BWC-03A, BWC-05B, BWC-07A, BWC-13, and BWC-36A during one or more of the water level measurement events. At locations where LNAPL was measured in temporary wells, the water level elevations measured in the wells were used to create the shallow groundwater surface maps.

In order to assess whether the presence of LNAPL significantly affects the actual groundwater elevations at those locations, the impact that actual LNAPL thickness (as opposed to measured LNAPL thickness) and corrected water level elevations was evaluated. This was done using the modified Zilliox and Muntzer equation (Hampton 1988) to estimate the corrected elevation of the groundwater in the wells with free product and to estimate the actual thickness of LNAPL zone above the water table. The modified Zilliox and Muntzer equation uses the apparent thickness of the LNAPL measured in the wells and density of the LNAPL to estimate the depression of the water level in the well.

The modified Zilliox and Muntzer equation is expressed as:

$$h = \frac{H(\rho_w - \rho_o)}{\rho_o}$$

Where:

h = Estimated thickness of free product in the aquifer

H = Measured thickness of free product in the well

ρ_w = Specific gravity of water (1.0 gram/cc)

ρ_o = Specific gravity of LNAPL

The measured LNAPL thickness at BWC-GW-36A was used to evaluate the effect of LNAPL on the water table because this location contained the greatest measured thickness of LNAPL (0.5 foot in November 2011 and February 2012). Further, the specific gravities for gasoline (0.74) and diesel fuel (0.88) were used for the LNAPL values. Using the equation above, the estimated actual LNAPL thickness is 0.18 foot for gasoline and 0.07 foot for diesel fuel. Therefore, the corrected water level elevation at BWC-GW-36A changes from the measured elevation of 920.22 to 920.54 (assuming the

LNAPL is gasoline) and from 920.22 to 920.69 (assuming the LNAPL is diesel fuel). This results in a corrected water level elevation of about 0.33 to 0.47 foot higher than actually measured. The higher (corrected) groundwater elevation does not have a significant effect on the general east to west groundwater flow pattern.

All other temporary well locations where LNAPL was observed typically had measured thicknesses of less than 0.1 foot and in many cases just a few hundredths of a foot. Therefore, calculating the estimated actual LNAPL thickness at location BWC-GW-07A (the second greatest measured LNAPL thickness of 0.11 foot) results in an actual estimated thickness of a few hundredths of a foot (depending on whether gasoline or diesel fuel specific gravity values are used) and results in a corrected groundwater elevation of about seven to nine hundredths of a foot higher than actually measured. Estimating actual LNAPL thicknesses and correcting groundwater elevations at temporary well locations where LNAPL was measured at thicknesses of just a few hundredths of a foot, results in even smaller (negligible) differences.

During the RI, four static water level gauging events were conducted (April, August, November 2011, and February 2012). In February 2012, water levels were measured concurrent with water level measurement activities conducted at the Union Tank Car site south of Holland Road to evaluate shallow groundwater flow patterns on a larger scale. Static water levels measured during each event for shallow and deep groundwater are shown in Tables 3-3 and 3-4.

Figure 22 shows the potentiometric surface for shallow groundwater in April 2011. As seen in Figure 22, the groundwater flow direction is primarily towards the southwest. The southern component of the flow pattern is influenced by the relatively higher groundwater elevations at BWC-GW-22 and BWC-GW-06. The soil boring log for BWC-GW-22 indicates that the temporary well screen is installed in predominantly silty clay with only small sand seams and traces of gravel present in the silty clay matrix. In addition, staining and product (creosote) was observed during soil boring advancement at BWC-GW-06; however, free-phase product was not observed in temporary wells installed at either location.

Figure 23 shows the potentiometric surface for shallow groundwater in August 2011. As seen in Figure 23, the groundwater flow direction is primarily from east to west with a slight southerly flow component evident on the western half of the BWC property.

Figure 24 shows the potentiometric surface for shallow groundwater in November 2011. As seen in Figure 24, the groundwater flow direction is primarily towards the southwest. The more southerly flow

pattern is influenced by the relatively higher groundwater elevations at BWC-GW-22 and BWC-GW-53. The soil boring logs for these two locations indicate that the temporary well screens are installed in predominantly silty clay with only small sand seams and traces of gravel present in the silty clay matrix. In addition, staining and product (creosote) was observed during soil boring advancement at BWC-GW-53; however, free-phase product was not observed in temporary wells installed at either location.

Figure 25 shows the potentiometric surface for shallow groundwater in February 2012 including select wells from the Union Tank Car site. Water level measurements were taken at Union Tank Car wells closest to Holland Road to evaluate shallow groundwater flow patterns on a larger scale (beyond the southern boundary of BWC) and to assess the relationship of shallow groundwater north and south of Holland Road. As seen in Figure 25, the groundwater flow direction is primarily from east to west with three distinct areas further influencing groundwater flow patterns. Two of the areas influencing the overall flow pattern include the relatively higher groundwater elevations previously discussed at BWC-GW-22 and BWC-GW-53. The third area exhibits relatively lower groundwater elevations observed at UTC-MW-2S and UTC-MW-17 in the central part of the Union Tank Car site south of Holland Road. As seen in Figure 25, shallow groundwater south of Holland Road generally flows toward the west with a slight northerly flow component. Shallow groundwater north of Holland Road generally flows toward the west with a slight southerly flow component. The predominant flow pattern south of Holland Road is consistent with previous monitoring results. For example, Figure 10 from the Union Tank Car soil and groundwater investigation report, work plan addendum 4 indicates that shallow groundwater south of Holland Road flows primarily from east to west with a slight northerly flow component (PSARA 2011).

Although the general groundwater flow direction is from east to west, several apparently anomalous groundwater elevations (both higher and lower) were observed at locations discussed above. Based on the geologic interpretation shown in the cross sections presented in Figures 14 through 20, it appears that the water producing units (sand, sand and gravel, weathered bedrock surface) may not be horizontally continuous across the entire BWC site and areas of perched groundwater may exist resulting in “false” representations of the actual water table.

In addition, one explanation for a southerly flow component north of Holland Road and a northerly flow component south of Holland Road might be that the sewer line running east-west under Holland Road may influence groundwater flow. In February 2012, a manhole cover was removed and the depth to water in the sewer was measured from a surveyed reference point. The water elevation in the sewer was

917.78 feet above msl. This elevation is approximately 3 feet lower than the nearest BWC temporary wells and approximately four feet lower than Union Tank Car wells UTC-MW-12 and UTC-MW-14 (but similar to the elevation at UTC-MW-2S). Therefore, it is possible that the sewer line might be acting as a discharge boundary for groundwater if water can enter the sewer through joints or cracks.

Figures 26 and 27 provide deep groundwater flow maps for water level measurements collected in August 2011 and February 2012. As shown in the figures, shallow and deep groundwater flow direction was confirmed to generally be in the westerly direction, consistent with conclusions from the Ohio EPA ESI report showing that groundwater is flowing in the westerly direction at the BWC site, toward the LSR (Ohio EPA 2003).

As shown in Tables 3-3 and 3-4, fluctuations were observed in static groundwater levels over each of the four sampling events. Static groundwater decreased in shallow monitoring wells by more than 2 feet from April 2011 to August 2011; increased by approximately 3 feet from August 2011 to November 2011; and decrease by almost 3 feet from November 2011 to February 2012. The changes are reflected using an average of site-wide elevations. The groundwater flow generally remains in the westerly direction throughout each of the four sampling events. Using the same methodology as for the shallow monitoring wells, static groundwater in deep monitoring wells decreased 2 feet from April 2011 to August 2011; increase by approximately 3 feet from August 2011 to November 2011; and decrease by approximately 3 feet from November 2011 to February 2012.

Groundwater horizontal hydraulic gradient at the BWC site was based on measurements from permanent shallow and deep groundwater monitoring wells MW1-S/MW1-D and MW3-S/MW3-D throughout each sampling event. In shallow monitoring wells, the hydraulic gradient ranges from 0.0011 feet/foot in April 2011 to 0.0024 feet/foot in August 2011 with an average of 0.0016 feet/foot over the four gauging events. In deep monitoring wells, hydraulic gradients range from 0.0011 feet/foot in April 2011 to 0.0022 feet/foot in August 2011, with an average of 0.0016 feet/foot over the four gauging events.

Table 3-3
Static Groundwater Levels in Shallow Monitoring Wells

Station ID	Top of Casing Elevation	Approximate Screen Depth (bgs)	Water Elevation April 2011	Water Elevation August 2011	Water Elevation November 2011	Water Elevation February 2012
BWC-GW-02A	935.28	12-17'	926.59	924.9	926.96	924.84
BWC-GW-03A	933.81	9-14'	926.28	924.68	927.75	924.68
BWC-GW-05	934.61	11.5-16.5'	926.99	922.61	925.19	922.36
BWC-GW-05B	932.49	11-16'	924.61	922.77	924.97	922.57
BWC-GW-06	932.98	8.5-13.5'	926.57	921.87	924.18	921.76
BWC-GW-06A	931.13	11.5-16.5'	922.22	920.99	922.59	920.77
BWC-GW-06C	933.19	11.5-16.5'	924.09	922.06	924.57	921.83
BWC-GW-06F	932.09	13-18'	923.09	921.47	923.77	921.8
BWC-GW-06H	932.18	11-16'	922.19	921.1	922.31	920.86
BWC-GW-06I	931.23	12-17'	922.57	921.15	923.28	920.98
BWC-GW-07A	930.64	12-17'	921.69	920.16	922.34	920.09
BWC-GW-09	928.30	8-13'	--	--	922.73	920.22
BWC-GW-13	932.72	13.5-18.5'	924.67	921.82	924.34	921.67
BWC-GW-14	933.70	13-18'	924.57	924.75	927.01	924.24
BWC-GW-15	933.29	10-15'	926.89	924.6	928.9	924.21
BWC-GW-22	933.80	12-17'	926.68	920.71	928.08	927.6
BWC-GW-23	930.20	12-17'	923.07	920.76	923.36	921.11
BWC-GW-25	929.53	9-14'	--	--	--	921.44
BWC-GW-28	932.53	13-18'	--	--	--	922.31
BWC-GW-34A	925.84	8-13'	921.91	918.39	922.86	919.16
BWC-GW-36A	926.55	8-13'	923.37	918.44	923.54	920.22
BWC-GW-51	931.26	11-16'	--	--	923.21	920.41
BWC-GW-53	933.15	6-16'	--	--	931.08	928.73
BWC-GW-54	928.09	8-13'	--	--	--	921.33
BWC-GW-55	926.12	5-10'	--	--	--	919.68
MW1-S	934.33	7-17'	924.34	922.73	925.31	922.51
MW2-S	935.68	5-15'	926.68	924.79	929.01	924.34
MW3-S	926.73	2.5-12.5'	922.34	918.3	923.16	919.11
MW4-S	932.34	5-15'	922.96	921.54	923.72	921.39
MW5-S	934.65	6-16'	924.27	922.49	925.26	922.48

Presented in mean sea level

Table 3-4
Static Groundwater Levels in Deep Monitoring Wells

Station ID	Top of Casing Elevation	Approximate Screen Depth (bgs)	Water Elevation April 2011	Water Elevation August 2011	Water Elevation November 2011	Water Elevation February 2012
MW1-D	933.78	28-38'	924.57	922.95	925.62	922.74
MW2-D	934.62	32.5-42.4'	924.71	922.9	925.98	922.76
MW3-D	926.16	34-44'	922.59	918.88	923.19	919.47
MW4-D	931.51	33-43'	923.67	922.16	927.54	922

Presented in mean sea level

Vertical hydraulic gradients were calculated by comparing measurements of static water levels in paired shallow and deep monitoring wells (see Table 3-5). As shown in Table 3-5, a potential upward vertical gradient is observed at all well pairs except for MW-2S/2D. In some circumstances such as at MW1-D/S and MW3-D/S, the static groundwater varies from several hundredths to several tenths of a foot. At well pairs MW2-D/S and MW4-D/S, static groundwater elevations differ by as much as several feet (see November 2011 water level elevations).

Table 3-5
Comparison of Static Groundwater Levels in Paired Monitoring Wells

Station ID	Water Elevation April 2011	Observed Vertical Gradient	Water Elevation August 2011	Observed Vertical Gradient	Water Elevation November 2011	Observed Vertical Gradient	Water Elevation February 2012	Observed Vertical Gradient
MW1-S	924.34		922.73	Upward	925.31		922.51	
MW1-D	924.57	Upward	922.95		925.62	Upward	922.74	Upward
MW2-S	926.68		924.79	Downward	929.01		924.34	
MW2-D	924.71	Downward	922.9		925.98	Downward	922.76	Downward
MW3-S	922.34		918.3	Upward	923.16		919.11	
MW3-D	922.59	Upward	918.88		923.19	Upward	919.47	Upward
MW4-S	922.96		921.54	Upward	923.72		921.39	
MW4-D	923.67	Upward	922.16		927.54	Upward	922	Upward

Presented in mean sea level

3.5 ECOLOGICAL HABITAT

The ecological habitat for the LSR and BWC sites is summarized below.

3.5.1 LSR Habitat

The Scioto River basin includes an area of approximately 6,510 square miles and more than 4,000 miles of rivers and streams, including the LSR. The headwaters of the LSR begin in Crawford County and flow south to its confluence with the Scioto River at Green Camp, Ohio, draining 113 square miles. The investigative portion of the LSR begins approximately 9 miles north of this confluence and includes LSR tributaries (Columbia Ditch, Rockswale Ditch, and North Rockswale Ditch). The LSR and tributary channels are predominantly vegetated with trees and overgrowth on banks that border agricultural fields.

Ecological assessments of the LSR performed by Ohio EPA (Ohio EPA 1988 and 1994) have identified the LSR as not attaining aquatic life status based on biocriteria for the Eastern Corn Belt Plains ecoregion of Ohio. These assessments included the sampling of macroinvertebrates (mussels) and fish (common carp and white sucker) that are common throughout the LSR.

Two bald eagles were identified in an agricultural field adjacent to the LSR in 2006. Several state endangered species, which include plants, reptiles, birds, and freshwater mussels, inhabit the LSR. This list was developed by Ohio EPA and is included in Appendix I (Ohio EPA 2007).

3.5.2 BWC Habitat

The BWC site is currently covered with a mix of secondary tree growth and scrub plant growth. The western two-thirds of the site is covered with thick tree growth. Large portions of unvegetated soils exist where significant concentrations of contaminants were detected.

Terrestrial sensitive environments were identified as habitats known to be used by state-endangered species and include the Plains garter snake (*Thamnophis radix*) and the five-angled dodder (*Cuscuta pentagona*). State threatened species identified include Leiberg's panic grass (*Panicum leibergi*), bearded wheat grass (*Elymus trachcaulus*), Philadelphia panic grass (*Panicum philadelphicum*), and prairie wedge grass (*Sphenopholis obtusata*). The bald eagle (*Haliaeetus leucocephalus*) was identified as a federally threatened species (Ohio EPA 2003).

4.0 NATURE AND EXTENT OF CONTAMINATION

This section presents information on the nature and extent of contamination at both the LSR and BWC sites. Because the nature of the RI at each area differs — as LSR was primarily a sediment and surface water investigation and BWC was primarily a soil and groundwater investigation — information pertaining to each site will be discussed separately.

The information used to delineate the nature and extent is based on the analysis of sediment, surface water, soil, and groundwater samples collected during the RI. Historical data are also used to provide further context in assessing potential impacts. Figures presenting analytical results were prepared to define the nature and extent of contamination in each area. Data presented on figures were developed to present the distribution of contaminants. Summary tables of the analytical results for LSR are provided in Appendix J. Summary tables of the analytical results for BWC are provided in Appendix K.

To assess whether a chemical is potentially of concern (exceeds natural conditions), and if so, the extent of its distribution, data were collected and compared with screening levels and established background concentrations, where available. These comparisons are not meant to present an evaluation of site risks, but rather to provide a preliminary indication of the potential for risk and to focus the discussion of the site.

4.1 LSR

Ecological and human health screening levels were developed for sediment, low-lying soil, surface water, and groundwater for the LSR site. Ecological screening levels (ESL) for sediment were developed using Ohio EPA Guidance on Evaluating Sediment Contamination Results (Ohio EPA 2010) and Sediment Reference Values (Ohio EPA 2008). In addition, the ESLs for sediment also use a total PAH concentration that compares the cumulative PAH risk to the total concentration of PAH compounds detected in the sample. SulTRAC calculated a total PAH concentration for each sediment sample. The total PAH concentration is the additive concentration of 16 PAH compounds and is calculated by adding all detections of all 16 compounds. If a compound was not detected over its sample quantitation limit (SQL), that compound is not included in the calculation and final total PAH concentration. Therefore, only detections are included. ESLs for groundwater and surface water were developed using Ohio EPA Ohio River Basin Aquatic Life and Human Health Criteria (Ohio EPA 2009).

Human health screening levels (HHSL) for sediment were developed using EPA Regional Screening Levels for residential soil (EPA 2011). HHSLs for groundwater and surface water were developed using

EPA Maximum Contaminant Levels (EPA 2009). If a maximum contaminant level (MCL) was not available, EPA Regional Screening Levels for tap water (EPA 2012) were used. HHSLs for fish and invertebrates were developed using EPA Regional Screening Levels for Fish Ingestion (EPA 2012).

To appropriately compare the data with project objectives, SulTRAC divided the LSR into five exposure areas:

- LSR-UP1 – this exposure area includes the portions of the LSR and NRD upgradient of the previous removal action
- LSR-DWN1 – this exposure area includes the portions of the LSR and NRD addressed during the previous removal action
- LSR-DWN2 – this exposure area includes the portion of the LSR where visual contamination was identified during previous investigations
- LSR-DWN3 – this exposure area includes the portion of the LSR down to the confluence with the Scioto River where no visual contamination was observed during previous investigations
- LSR-DWN4 – this exposure area includes the ditches and waterways adjacent to LSR, including Rockswale and Columbia Ditches

Tables J-1 through J-15 in Appendix J present analytical results for all samples collected during the LSR investigation. Figures 28 through 33 present sample results by medium that exceed one or more established screening levels. Figure 28 presents LSR sediment sampling results that exceed screening levels. Figure 29 presents LSR surface water sampling results that exceed screening levels. Figure 30 presents low-lying soils and connecting water way sediment results that exceed screening levels. Figure 31 presents LSR invertebrate sampling results that exceed screening levels. Figure 32 presents LSR fish sampling results that exceed screening levels. Figure 33 presents LSR groundwater sampling results that exceed screening levels.

The nature and extent of contamination identified in these areas relative to human health and aquatic life for each type of analysis are discussed in the following subsections.

4.1.1 Extent of Contamination – Exposure Area LSR-UP1

A total of six sediment and surface water samples, not including duplicate samples, were collected from six sample locations within waterways (LSR and NRD) upstream of the previous removal action to identify any upstream sources or impacts as well as obtain representative upstream sample concentrations. All sediment samples were collected from 0 to 6 inches bgs. Each sediment and surface water sample was analyzed for TCL SVOCs, TAL metals, mercury, and cyanide. Sediment samples were also analyzed for TOC. Surface water samples were also analyzed for hardness. In addition, one invertebrate sample was collected from this area and analyzed for PAHs (by EPA Method 8270-SIM), TAL metals, and percent lipids.

Figure 34 presents all sample locations within Exposure Area LSR-UP1 that exceeded one or more established screening levels.

4.1.1.1 Sediment SVOCs

Nine SVOCs (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, fluoranthene, fluorene, phenanthrene, and pyrene) were detected at concentrations exceeding their ESLs and or HHSLs.

ESLs

Sample location LSR-SD-24 contained fluoranthene, fluorene, phenanthrene, and pyrene at concentrations exceeding the ESLs. Sample location LSR-SD-24 also exceeded the total PAH ESL of 1.61 milligrams per kilogram (mg/kg); the total PAH concentration at LSR-SD-24 was 2.03 mg/kg in the duplicate sample. Sample location NRD-SD-04 contained benzo(a)pyrene and pyrene at concentrations exceeding the ESLs. Sample location NRD-SD-05 contained benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, and chrysene at concentrations exceeding the ESLs. No other sediment sample locations contained SVOC concentrations exceeding ESLs.

HHSLs

Sample location NRD-SD-04 contained benzo(a)pyrene at a concentration (0.18 mg/kg) exceeding its HHSL of 0.015 mg/kg. Sample location NRD-SD-05 contained benzo(a)anthracene (0.17 mg/kg), benzo(a)pyrene (0.25 mg/kg), and benzo(b)fluoranthene (0.27 mg/kg) at concentrations exceeding the

HHSLs (the HHSL for all three compounds is 0.15 mg/kg). No other sediment sample locations contained SVOC concentrations exceeding the HHSLs.

4.1.1.2 Sediment Inorganics

Seven inorganic compounds (antimony, arsenic, beryllium, copper, nickel, silver, and zinc) were detected at concentrations exceeding the ESLs or HHSLs.

ESLs

Sample location LSR-SD-24 contained concentrations of contaminants exceeding ESLs as follows: antimony (0.97 mg/kg compared to ESL of 0.92 mg/kg), beryllium (1.8 mg/kg compared to ESL of 0.8 mg/kg), copper (61.7 mg/kg compared to ESL of 31.6 mg/kg), and silver (2.2 mg/kg compared to ESL of 0.5 mg/kg).. Sample location LSR-SD-25 contained concentrations of contaminants exceeding ESLs as follows: beryllium (2.5 mg/kg compared to ESL of 0.8 mg/kg) and silver (5.1 mg/kg compared to ESL of 0.5 mg/kg). Sample location LSR-SD-26 contained concentrations of contaminants exceeding ESLs as follows: antimony (0.99 mg/kg compared to ESL of 0.92 mg/kg), beryllium (1.9 mg/kg compared to ESL of 0.8 mg/kg), and silver (4.5 mg/kg compared to ESL of 0.5 mg/kg). Sample location NRD-SD-03 contained concentrations of contaminants exceeding ESLs as follows: beryllium (3.6 mg/kg compared to ESL of 0.8 mg/kg) and silver (4.7 mg/kg compared to 0.5 mg/kg). Sample location NRD-SD-04 contained concentrations of contaminants exceeding ESLs as follows: nickel (38.4 mg/kg compared to ESL of 22.7 mg/kg), silver (40.0 mg/kg compared to ESL of 0.5 mg/kg), and zinc (239 mg/kg compared to 121 mg/kg). Sample location NRD-SD-06 contained a concentration of silver (18.9 mg/kg) exceeding its ESL of 0.5 mg/kg.

HHSLs

All six sediment sample locations collected from within this exposure area contained concentrations of arsenic ranging from 4.2 mg/kg to 8.1 mg/kg, exceeding its HHSL of 0.39 mg/kg. No other sampling locations in this exposure area contained inorganic compounds at concentrations exceeding the HHSLs.

4.1.1.3 Surface Water SVOCs

No SVOCs were detected at concentrations exceeding the ESLs or HHSLs.

4.1.1.4 Surface Water Inorganic Compounds

Two inorganic compounds (cyanide and silver) were detected at concentrations exceeding the ESLs and or HHSLs.

ESLs

Silver was detected in sample locations LSR-SW-24, LSR-SW-25, and LSR-SW-26 at concentrations ranging from 6.5 micrograms per liter (µg/L) to 9.4 µg/L, exceeding its ESL of 1.3 µg/L. Cyanide was detected in sample locations NRD-SW-04 and NRD-SW-05 at concentrations of 9.0 µg/L and 11.8 µg/L, exceeding its ESL of 5.2 µg/L.

HHSLs

No surface water samples collected in this exposure area contained concentrations of inorganic compounds exceeding the HHSLs.

4.1.1.5 Invertebrate Results

Three PAHs (benzo[a]pyrene, benzo[b]fluoranthene, and dibenzo[a,h]anthracene) and two inorganic compounds (arsenic and manganese) were detected at one invertebrate sample location at concentrations exceeding the HHSLs.

Sample location LSR-IT-03 contained benzo(a)pyrene at a concentration of 0.004 mg/kg, exceeding its HHSL of 0.00043 mg/kg; benzo(b)fluoranthene at a concentration of 0.0048 mg/kg, exceeding its HHSL of 0.0043 mg/kg; and dibenzo(a,h)anthracene at a concentration of 0.001 mg/kg, exceeding its HHSL of 0.00043 mg/kg.

Sample location LSR-IT-03 also contained arsenic at a concentration of 0.55 mg/kg, exceeding its HHSL of 0.0021 mg/kg, and manganese at a concentration of 589 mg/kg, exceeding its HHSL of 190 mg/kg.

4.1.1.6 Exposure Area LSR-UP1 Summary

Based on the analytical results for this exposure area, the following analytes were detected in various media exceeding one or more screening levels: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, phenanthrene, pyrene, antimony, arsenic, beryllium, cyanide, nickel, silver, and zinc. Sediment, surface water, and invertebrate sampling results are summarized below.

Sediment

Analytes benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, phenanthrene, pyrene, antimony, arsenic, antimony, beryllium, copper, cyanide, nickel, silver, and zinc were detected in sediment samples at concentrations exceeding one or more screening levels. Of the analytes that exceeded sediment screening levels, the majority exceeded the ESLs.

To better define the lateral extent of PAH contamination identified in the sediment samples collected from this exposure area, SulTRAC compared the RI sample analytical results with historical samples. The northern extent of LSR PAH contamination appears to be between sample location LSR-SD-24 (total PAH concentration of 2.03 mg/kg) and the 1998 sample collected at river mile 7.02 (total PAH concentration of 1.558 mg/kg). The total PAH concentration at sample location LSR-SD-24 was slightly greater than the total PAH ESL concentration of 1.61 mg/kg. However, this sample location is located just north of the previous removal action area. The total PAH concentration calculated from sample location LS-26 (total PAH concentration of 102.78 mg/kg), located closer to the removal area and collected in 1999, was much higher, indicating that either re-suspension of contaminated sediment has occurred or that the previous removal action did not completely address sediment contamination present in the area of sample location LSR-SD-24.

An area of elevated SVOC concentrations is present at sample location NRD-SD-05 and beyond the 1998 sample collected from the NRD at river mile 2.5. The concentrations of elevated PAHs detected at sample location NRD-SD-05 (total PAH concentration of 1.21 mg/kg) are less than concentrations present in the upstream sample collected in 1998 (total PAH concentration of 10.71 mg/kg). Both sample locations are slightly downstream of a railroad, a common source of PAH contamination. Based on sediment samples collected farther downstream in NRD, this area is not considered a current source of PAH contamination to LSR. Total PAH concentrations (where available) for sediment samples collected throughout this area are presented on Tables J-1 and J-3.

A comparison of inorganic sample analytical results with historical results indicates that arsenic is present throughout the area at concentrations exceeding its HHSL. Silver was also detected in sediment samples collected throughout the exposure area, exceeding its ESL. The sources of inorganic contamination are unknown; however, NRD has historically received discharges from combined sewer overflows (CSO), which could be contributing to the concentrations detected.

Analytical results for sediment samples obtained from sample location LSR-SD-24 indicate that this upstream area likely contains contamination that was not addressed during the previous removal action. Therefore, those sample results are not likely representative of upstream background conditions and are not included in the discussion of the semi-quantitative comparison to downstream exposure area sediment sample results presented in subsequent sections.

Surface Water

Analytes cyanide and silver were detected in surface water samples at concentrations exceeding one or more screening levels. Of the analytes that exceeded surface water screening levels, all exceeded the ESLs.

Cyanide was detected above its ESL at two sample locations (NRD-SW-04 and NRD-SW-05) within NRD. Silver was detected above its ESL in all three sample locations (LSR-SW-24, LSR-SW-25, and LSR-SW-26) within the LSR in this exposure area. The highest concentration of cyanide was detected at sample location NRD-SW-05, and the highest concentration of silver was detected at sample location LSR-SW-24.

Surface water sample results from exposure area LSR-UP1 are assumed to indicate upstream background conditions and are included in the discussion of semi-quantitative comparison to downstream exposure area surface water sample results presented in subsequent sections.

Invertebrates

Analytes benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, arsenic, and manganese were detected above their respective HHSLs in the invertebrate sample (LSR-IT-03) collected in this exposure area.

Invertebrate results from area LSR-UP1 are available for one sample. Although there are limited data available from this exposure area, the results are used for making general comparisons between upstream background conditions and results from downstream exposure area sample results presented in subsequent sections.

4.1.2 Extent of Contamination – Exposure Area LSR-DWN1

A total of six sediment and surface water samples, not including duplicate samples, were collected from six sample locations within the previous removal action area of the LSR (four sample locations within the LSR and two sample locations within the NRD) to determine whether residual PAH and metals contamination from the previous removal action remains and if the existing fish population within the LSR is being exposed to residual contamination in this exposure area. All sediment samples were collected from 0- to 6-inches bgs. Each sediment and surface water sample was analyzed for TCL SVOCs, TAL metals, mercury, and cyanide. Sediment samples were also analyzed for TOC. Surface water samples were also analyzed for hardness. In addition, 12 fish tissue samples (six carcass and six fillet) were collected from this exposure area. Three fish tissue samples (one carcass and two fillet) were analyzed for TCL SVOCs, PAHs (by EPA Method 8270-SIM), TAL metals, and percent lipids. Nine fish tissue samples (five carcass and four fillet) were analyzed for PAHs (by EPA Method 8270-SIM), TAL metals, and percent lipids.

Five groundwater samples were also collected from five temporary monitoring wells located adjacent to the LSR near Holland Road. These samples were collected to assess whether shallow groundwater is being contaminated by LSR sediments. The groundwater samples were analyzed for TCL VOCs, TCL SVOCs, TAL metals, mercury, and cyanide.

Figure 35 presents all sample locations within Exposure Area LSR-DWN1 that exceeded one or more established screening levels.

4.1.2.1 Sediment SVOCs

Fourteen SVOCs (anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-c,d]pyrene, naphthalene, phenanthrene, and pyrene) were detected in sediment samples at concentrations exceeding one or more screening levels.

ESLs

Anthracene was detected in four sediment samples at four sample locations (all within the LSR) at concentrations ranging from 0.15 mg/kg to 0.85 mg/kg, exceeding its ESL of 0.0572 mg/kg.

Benzo(a)anthracene was detected in five sediment samples at five locations (four within the LSR and one within NRD) at concentrations ranging from 0.15 mg/kg to 2.70 mg/kg, exceeding its ESL of 0.108

mg/kg. Benzo(a)pyrene was detected in five sediment samples at five locations (four within the LSR and one within NRD) at concentrations ranging from 0.26 mg/kg to 2.00 mg/kg, exceeding its ESL of 0.15 mg/kg. Benzo(g,h,i)perylene was detected in four sediment samples at four sample locations (all within the LSR) at concentrations ranging from 0.3 mg/kg to 0.98 mg/kg, exceeding its ESL of 0.17 mg/kg. Benzo(k)fluoranthene was detected in five sediment samples at five locations (four within the LSR and one within NRD) at concentrations ranging from 0.25 mg/kg to 1.90 mg/kg, exceeding its ESL of 0.24 mg/kg. Chrysene was detected in five sediment samples at five locations (four within the LSR and one within the NRD) at concentrations ranging from 0.26 mg/kg to 3.40 mg/kg, exceeding its ESL of 0.166 mg/kg. Dibenzo(a,h)anthracene was detected in three sediment samples at three sample locations (all within the LSR) at concentrations ranging from 0.20 mg/kg to 0.28 mg/kg, exceeding its ESL of 0.033 mg/kg. Fluoranthene was detected in four sediment samples at four sample locations (all within the LSR) at concentrations ranging from 0.55 mg/kg to 8.00 mg/kg, exceeding its ESL of 0.423 mg/kg. Fluorene was detected in three sediment samples at three sample locations (all within the LSR) at concentrations ranging from 0.13 mg/kg to 1.40 mg/kg, exceeding its ESL of 0.0774 mg/kg. Indeno(1,2,3-cd)pyrene was detected in four sediment samples at four sample locations (all within the LSR) at concentrations ranging from 0.25 mg/kg to 0.78 mg/kg, exceeding its ESL of 0.2 mg/kg. Naphthalene was detected in one sediment sample within the LSR at a concentration of 0.19 mg/kg, exceeding its ESL of 0.176 mg/kg. Phenanthrene was detected in four sediment samples at four sample locations (all within the LSR) at concentrations ranging from 0.27 mg/kg to 7.40 mg/kg, exceeding its ESL of 0.204 mg/kg. Pyrene was detected in four sediment samples at four sample locations (all within the LSR) at concentrations ranging from 0.43 mg/kg to 5.90 mg/kg, exceeding its ESL of 0.195 mg/kg.

A total PAH concentration was calculated for all six sediment samples collected in this exposure area. The four sample locations within the LSR had total PAH concentrations ranging from 3.42 mg/kg to 40.29 mg/kg, all exceeding the total ESL PAH concentration of 1.61 mg/kg. The total PAH concentration at sample location NRD-SD-01 was 1.20 mg/kg, below the total ESL PAH concentration of 1.61 mg/kg. No PAHs were detected at the second sample location within the NRD, NRD-SD-02; therefore, no total PAH concentration was calculated.

HHSLs

Benzo(a)anthracene was detected in four sediment samples at four sample locations (all within the LSR) at concentrations ranging from 0.22 mg/kg to 2.70 mg/kg, exceeding its HHSL of 0.15 mg/kg. Benzo(a)pyrene was detected in five sediment samples at five sample locations (four within LSR and one within NRD) at concentrations ranging from 0.26 mg/kg to 2.0 mg/kg, exceeding its HHSL of 0.015

mg/kg. Benzo(b)fluoranthene was detected in five sediment samples at five sample locations (four within LSR and one within NRD) at concentrations ranging from 0.27 mg/kg to 2.50 mg/kg, exceeding its HHSL of 0.15 mg/kg. Benzo(k)fluoranthene was detected in one sediment sample within the LSR at a concentration of 1.90 mg/kg, exceeding its HHSL of 1.5 mg/kg. Dibenzo(a,h)anthracene was detected in three sediment samples at three sample location within the LSR at concentrations ranging from 0.2 mg/kg to 0.28 mg/kg, exceeding its HHSL of 0.015 mg/kg. Indeno(1,2,3-cd)pyrene was detected in four sediment samples at four sample locations (all within the LSR) at concentrations ranging from 0.25 mg/kg to 0.78 mg/kg, exceeding its HHSL of 0.15 mg/kg.

4.1.2.2 Sediment Inorganic Compounds

Eight inorganic compounds (antimony, arsenic, beryllium, chromium, copper, nickel, silver, and zinc) were detected in sediment samples at concentrations exceeding one or more screening level.

ESLs

Antimony was detected in four sediment samples collected from four sample locations (two within the LSR and two within the NRD) at concentrations ranging from 0.94 mg/kg to 1.9 mg/kg, exceeding its ESL of 0.92 mg/kg. Arsenic was detected in four sediment samples collected from four sample locations (two within the LSR and two within the NRD) at concentrations ranging from 10.5 mg/kg to 14.1 mg/kg, exceeding its ESL of 9.79 mg/kg. Beryllium was detected in four sediment samples collected from four sample locations all within the LSR at concentrations ranging from 2.7 mg/kg to 6.7 mg/kg, exceeding its ESL of 0.8 mg/kg. Chromium was detected in one sediment sample collected from within LSR at a concentration of 51.9 mg/kg, exceeding its ESL of 43.4 mg/kg. Copper was detected in four sediment samples collected from four sample locations (three within the LSR and one within NRD) at concentrations ranging from 36.4 mg/kg to 54 mg/kg, exceeding its ESL of 31.6 mg/kg. Nickel was detected in all six sediment samples collected in the exposure area at concentrations ranging from 24.9 mg/kg to 40.4 mg/kg, exceeding its ESL of 22.7 mg/kg. Silver was also detected in all six sediment samples collected within the exposure area at concentrations ranging from 4.5 mg/kg to 7.7 mg/kg, exceeding its ESL of 0.5 mg/kg. Zinc was detected in three sediment samples located within the LSR at concentrations ranging from 129 mg/kg to 160 mg/kg, exceeding its ESL of 121 mg/kg.

HHSLs

Arsenic was detected in all six sediment samples collected in the exposure area at concentrations ranging from 5.9 mg/kg to 14.1 mg/kg, exceeding its HHSL of 0.369 mg/kg.

4.1.2.3 Surface Water SVOCs

One SVOC (bis(2-ethylhexyl)phthalate) was detected in surface water samples at concentrations exceeding one or more screening level.

ESLs

Bis(2-ethylhexyl)phthalate was detected in two surface water samples collected from two sample locations within the NRD at concentrations ranging from 59 µg/L to 70 µg/L, exceeding its ESL of 8.4 µg/L.

HHSLs

Bis(2-ethylhexyl)phthalate was detected in two surface water samples collected from two sample locations within the NRD at concentrations ranging from 59 µg/L to 70 µg/L, exceeding its HHSL of 6.0 µg/L.

4.1.2.4 Surface Water Inorganic Compounds

Two inorganics (copper and silver) were detected in surface water samples at concentrations exceeding one or more screening level.

ESLs

Copper was detected in one surface water sample collected from within the LSR (LSR-SW-22) at a concentration of 9.7 µg/L exceeding its ESL of 9.3 µg/L. Silver was detected in three surface water samples collected from within the LSR (LSR-SW-21, LSR-SW-22, and LSR-SW-23) at concentrations ranging from 6.3 µg/L to 10.0 µg/L, exceeding its ESL of 1.3 µg/L.

HHSLs

No surface water samples collected in this exposure area contained concentrations of inorganic compounds exceeding the HHSLs.

4.1.2.5 Fish Tissue Samples

Four PAHs (benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, and dibenzo[a,h]anthracene) and one inorganic compound (arsenic) were detected in fish tissue samples at concentrations exceeding one or more HHSL.

PAHs

Benzo(a)pyrene was detected in five fish tissue samples collected from within the exposure area at concentrations ranging from 0.00092 mg/kg to 0.0067 mg/kg, exceeding its HHSL of 0.00043 mg/kg.

Benzo(a)anthracene was detected in three fish tissue samples collected from within the LSR at concentrations ranging from 0.0081 mg/kg to 0.009 mg/kg, exceeding its HHSL of 0.0043 mg/kg.

Benzo(b)fluoranthene was detected in two fish tissue samples collected from within the LSR at concentrations ranging from 0.0072 mg/kg to 0.0108 mg/kg, exceeding its HHSL of 0.0043 mg/kg.

Dibenzo(a,h)anthracene was detected in one fish tissue sample collected from within the LSR at a concentration of 0.00056 mg/kg exceeding its HHSL of 0.00043 mg/kg.

Inorganic Compounds

Arsenic was detected in 10 fish tissue samples collected from within the exposure area at concentrations ranging from 0.039 mg/kg to 0.14 mg/kg, exceeding its HHSL of 0.0021 mg/kg.

4.1.2.6 Groundwater

No SVOCs were detected in groundwater samples at concentrations exceeding ESLs or HHSLs.

Four inorganic compounds (barium, copper, iron, and lead) were detected in groundwater samples at concentrations exceeding one or more screening level.

ESLs – Inorganics

Barium was detected in four groundwater samples collected from four sample locations at concentrations ranging from 257 µg/L to 5,540 µg/L, exceeding its ESL of 220 µg/L. Copper and lead were detected in one groundwater sample collected from sample location LSR-TW-10 at concentrations of 13.6 µg/L copper and 12.4 µg/L lead, exceeding their ESLs of 9.3 µg/L copper and 6.4 µg/L lead.

HHSLs – Inorganic Compounds

Barium was detected in one groundwater sample collected from sample location LSR-TW-06 at a concentration of 5,540 µg/L, exceeding its HHSL of 2,000 µg/L. Iron was detected in one groundwater sample collected from sample location LSR-TW-10 at a concentration of 17,300 µg/L, exceeding its HHSL of 11,000 µg/L.

4.1.2.7 Exposure Area LSR-DWN1 Summary

Based on the analytical results for this exposure area, the following analytes were detected in various media exceeding one or more screening levels: anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, phenanthrene, pyrene, antimony, arsenic, barium, beryllium, chromium, copper, iron, lead, nickel, silver, and zinc.

Sediment

Analytes anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, phenanthrene, pyrene, antimony, arsenic, beryllium, chromium, copper, nickel, silver, and zinc were detected in sediment samples at concentrations exceeding one or more screening level. Of the analytes that exceeded sediment screening levels, the majority exceeded their respective ESLs.

Of the two sediment samples collected in the NRD, the easternmost sample (NRD-SD-02) did not contain concentrations of PAHs exceeding ESLs or HHSLs. The westernmost sample (NRD-SD-01) closest to LSR, contained concentrations of PAHs exceeding both ESLs and HHSLs; however, the total PAH concentration for this sample was 1.20 mg/kg, below the total ESL PAH concentration of 1.61 mg/kg. Although the total PAH concentration does not exceed the total ESL PAH concentration, the presence of PAHs in this area could indicate that residual contamination above the screening levels remains; however, concentrations of PAHs are similar to those detected in upstream samples, specifically at NRD-SD-05. Although both sediment samples collected in this exposure area from NRD contained inorganic compounds, the concentrations are similar to those detected in the upstream samples as well as historical sample results. Inorganic concentrations in the NRD mainly exceeded ESLs.

The total PAH concentrations of all four sediment samples collected in the LSR portion of this exposure area exceed the total ESL PAH concentration of 1.61 mg/kg. The lateral extent of PAH contamination in this area appears to include the entire length of the previously remediated LSR and a small portion of the NRD (between the LSR confluence and sediment sample NRD-SD-01). Although the total PAH concentrations are significantly less than the historical concentration detected prior to EPA's removal action, PAHs are still present at concentrations above screening levels; therefore, either the removal action was not able to excavate all residual contamination, PAH contamination at upstream location LSR-SD-24 may be re-suspended and has transported downstream, or runoff into LSR may be impairing sediment quality.

Surface Water

Bis(2-ethylhexyl)phthalate was detected at both surface water sample locations collected from the NRD at concentrations exceeding both its ESL and HHSL. This chemical was not detected in either sediment sample collocated with each sample or in any upstream surface water or sediment samples.

SVOCs were not detected at concentrations exceeding ESLs or HHSLs in any of the surface water samples collected in the LSR portion of this exposure area, indicating that PAHs detected in LSR sediments in this exposure area are most likely immobile or at least not migrating to surface water.

No inorganic compounds were detected in surface water samples collected from the NRD at concentrations exceeding ESLs or HHSLs. Silver was detected in three of the surface water samples at concentrations exceeding its ESL from samples collected in the LSR portion of the exposure area. Although the concentrations of silver are above the ESL, upstream surface water samples collected at locations LSR-SW-24, LSR-SW-25, and LSR-SW-26 contained silver concentrations ranging from 6.5 J- to 9.4 J- $\mu\text{g/L}$, comparable to those detected in this exposure area.

Fish Tissue

PAHs were detected in five fish tissue samples collected from this portion of the exposure area. Of the five tissue samples, PAHs were detected in one fillet and four carcass samples. Arsenic was detected in 10 of the 12 fish tissue samples collected from this portion of the exposure area. Of the 10 tissue samples, arsenic was detected in four fillet and six carcass samples. PAHs and arsenic were also detected above screening levels in sediments in this exposure area.

Groundwater

No SVOCs were detected at concentrations exceeding ESLs or HHSLs in this exposure area. PAHs were detected in sediments in this exposure area but not in the groundwater samples, which may indicate that contaminants from surface sediments are not migrating outward to the shallow aquifer.

Barium was detected in four groundwater samples at concentrations exceeding its ESL and at one location (LSR-TW-06) exceeding its HHSL. Copper, iron, and lead were also detected in one groundwater sample collected at LSR-TW-10 at concentrations exceeding a screening level. Of these, only copper was detected in sediment samples exceeding its ESL.

4.1.3 Extent of Contamination – Exposure Area LSR-DWN2

A total of 12 sediment and nine surface water samples, not including duplicate samples, were collected from nine sample locations within a 3.5-mile stretch of the LSR downstream of the previous removal action, where visual impacts were historically observed. The sediment and surface water samples were collected to delineate the nature and extent of impacts relative to established screening levels in this portion of the LSR. A sediment sample was collected from 0 to 6 inches bgs at all nine sample locations. A deeper sediment sample was collected at three sample locations (LSR-SD-11, LSR-SD-16, and LSR-SD-17) based on the visual presence of possible creosote contamination. Each sediment and surface water sample was analyzed for TCL SVOCs, TAL metals, mercury, cyanide, and TOC. Five of the sediment samples were also analyzed for AVS/SEM. Surface water samples were also analyzed for hardness.

In addition, 20 fish tissue samples (10 fillet and 10 carcass) and five invertebrate samples were collected from this exposure area and analyzed for PAHs (by EPA Method 8270-SIM), TAL metals, and percent lipids.

Four surface soil samples collected from four sample locations from low-lying areas adjacent to the LSR were also collected from this exposure area. The surface soil samples were collected to evaluate potential contamination from sediment deposition when the river overflows its banks during high water. The surface soil samples were analyzed for TCL SVOCs, TAL metals, mercury, and cyanide.

A total of 11 groundwater samples were collected from 11 temporary monitoring wells located in two areas adjacent to the LSR. The first group of temporary wells is located at State Route 95 (six sample locations), and the second group is located downstream at Keener Pike (five sample locations). The groundwater samples were collected to assess whether shallow groundwater is being contaminated by LSR sediments. The groundwater samples were analyzed for TCL VOCs, TCL SVOCs, TAL metals, mercury, and cyanide.

Figure 36 presents all sample locations within Exposure Area LSR-DWN2 that exceeded one or more established screening levels.

4.1.3.1 Sediment SVOCs

Sixteen SVOCs (2-methylnaphthalene, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, dibenzofuran, fluoranthene, fluorene, indeno[1,2,3-c,d]pyrene, naphthalene, phenanthrene, and pyrene) were detected in sediment samples at concentrations exceeding one or more screening level.

ESLs

Anthracene was detected in nine sediment samples collected from the 0- to 6-inch interval at concentrations ranging from 3.9 mg/kg to 300 mg/kg, exceeding its ESL of 0.0572 mg/kg. Anthracene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 2.3 mg/kg to 1,100 mg/kg, also exceeding its ESL of 0.0572 mg/kg. Benzo(a)anthracene was detected in nine sediment samples collected from the 0- to 6-inch interval at concentrations ranging from 4.9 mg/kg to 230 mg/kg, exceeding its ESL of 0.108 mg/kg. Benzo(a)anthracene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 3.9 mg/kg to 810 mg/kg, also exceeding its ESL of 0.108 mg/kg. Benzo(a)pyrene was detected in nine sediment samples collected from the 0- to 6-inch interval at concentrations ranging from 4.8 mg/kg to 140 mg/kg, exceeding its ESL of 0.15 mg/kg. Benzo(a)pyrene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 3.7 mg/kg to 960 mg/kg, also exceeding its ESL of 0.15 mg/kg. Benzo(b)fluoranthene was detected in eight sediment samples collected from the 0- to 6-inche interval at concentrations ranging from 14 mg/kg to 120 mg/kg, exceeding its ESL of 10.4 mg/kg. Benzo(b)fluoranthene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 4.3 mg/kg to 880 mg/kg, also exceeding its ESL of 10.4 mg/kg. Benzo(g,h,i)perylene was detected in eight sediment samples collected from the 0- to 6-inch interval at concentrations ranging from 2.7 mg/kg to 94 mg/kg, exceeding its ESL of 0.17 mg/kg. Benzo(g,h,i)perylene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 2.4 mg/kg to 520 mg/kg, also exceeding its ESL of 0.17 mg/kg. Benzo(k)fluoranthene was detected in nine sediment samples collected from the 0- to 6-inch interval at concentrations ranging from 3.8 mg/kg to 150 mg/kg, exceeding its ESL of 0.24 mg/kg. Benzo(k)fluoranthene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 3.9 mg/kg to 820 mg/kg, also exceeding its ESL of 0.24 mg/kg. Chrysene was detected in nine sediment samples collected from the 0- to 6-inch interval at concentrations ranging from 5.5 mg/kg to 300 mg/kg, exceeding its ESL of 0.166 mg/kg. Chrysene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 4.6 mg/kg to 1,200 mg/kg, also exceeding its ESL of 0.166 mg/kg. Dibenzo(a,h)anthracene was detected in five samples collected from the 0- to 6-inch interval at concentrations ranging from 1.0 mg/kg to 18 mg/kg, exceeding

its ESL of 0.033 mg/kg. Dibenzo(a,h)anthracene was detected in two samples collected from greater than 6-inches bgs at concentrations ranging from 3.9 mg/kg to 190 mg/kg, also exceeding its ESL of 0.33 mg/kg. Dibenzofuran was detected in seven samples collected from the 0- to 6-inch interval at concentrations ranging from 0.5mg/kg to 74 mg/kg, exceeding its ESL of 0.449 mg/kg. Dibenzofuran was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 0.28 mg/kg to 650 mg/kg, also exceeding its ESL of 0.449 mg/kg. Fluoranthene was detected in nine sediment samples collected from the 0- to 6-inch interval at concentrations ranging from 8 mg/kg to 410 mg/kg, exceeding its ESL of 0.423 mg/kg. Fluoranthene was detected in three samples collected from greater than 6- inches bgs at concentrations ranging from 13 mg/kg to 2,000 mg/kg, also exceeding its ESL of 0.423 mg/kg. Fluorene was detected in six samples collected from the 0- to 6-inch interval at concentrations ranging from 2.2 mg/kg to 110 mg/kg, exceeding its ESL of 0.0774 mg/kg. Fluorene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 2.5 mg/kg to 940 mg/kg, also exceeding its ESL of 0.0774 mg/kg. Indeno(1,2,3-c,d)pyrene was detected in eight samples collected from the 0- to 6-inch interval at concentrations ranging from 2.3 mg/kg to 65 mg/kg, exceeding its ESL of 0.2 mg/kg. Indeno(1,2,3-cd)pyrene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 2 mg/kg to 460 mg/kg, also exceeding its ESL of 0.2 mg/kg. Naphthalene was detected in six samples collected from the 0- to 6-inch interval at concentrations ranging from 0.25 mg/kg to 310 mg/kg, exceeding its ESL of 0.176 mg/kg. Naphthalene was detected in one sample collected from greater than 6-inches bgs at a concentration of 390 mg/kg, also exceeding its ESL of 0.176 mg/kg. Phenanthrene was detected in eight samples collected from the 0- to 6-inch interval at concentrations ranging from 1.6 mg/kg to 600 mg/kg, exceeding its ESL of 0.204 mg/kg. Phenanthrene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 0.58 mg/kg to 4,000 mg/kg, also exceeding its ESL of 0.204 mg/kg. Pyrene was detected in nine sediment samples collected from the 0- to 6-inch interval at concentrations ranging from 6.7 mg/kg to 310 mg/kg, exceeding its ESL of 0.195 mg/kg. Pyrene was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 9.8 mg/kg to 1,400 mg/kg, also exceeding its ESL of 0.195 mg/kg.

The total PAH concentrations calculated for the nine surface sediment samples (0- to 6-inches bgs) ranged from 60.89 mg/kg to 3,096.00 mg/kg. All exceed the total ESL PAH concentration of 1.61 mg/kg.

The total PAH concentrations calculated for the three deep sediment samples (greater than 6 inches bgs) ranged from 58.01 mg/kg to 16,470.00 mg/kg. All three deep sediment samples exceed the total ESL PAH concentration of 1.61 mg/kg.

HHSLs

2-Methylnaphthalene was detected in one sample collected from more than 6 inches bgs at a concentration of 800, exceeding its HHSL of 310 mg/kg. Benzo(a)anthracene was detected in 12 sediment samples (nine surface and three deep) at concentrations ranging from 3.9 mg/kg to 810 mg/kg, exceeding its ESL of 0.15 mg/kg. Benzo(a)pyrene was detected in 12 sediment samples (nine surface and three deep) at concentrations ranging from 3.7 mg/kg to 960 mg/kg, exceeding its HHSL of 0.015 mg/kg. Benzo(b)fluoranthene was detected in 12 sediment samples (nine surface and three deep) at concentrations ranging from 4.3 mg/kg to 880 mg/kg, exceeding its HHSL of 0.15 mg/kg. Benzo(k)fluoranthene was detected in 12 sediment samples (nine surface and three deep) at concentrations ranging from 3.8 mg/kg to 820 mg/kg, exceeding its HHSL of 1.5 mg/kg. Chrysene was detected in 10 sediment samples (eight surface and two deep) at concentrations ranging from 17 mg/kg to 1,200 mg/kg, exceeding its HHSL of 15 mg/kg. Dibenzo(a,h)anthracene was detected in seven sediment samples (five surface and two deep) at concentrations ranging from 0.79 mg/kg to 190 mg/kg, exceeding its HHSL of 0.015 mg/kg. Indeno(1,2,3-c,d)pyrene was detected in 11 samples (10 eight surface and three deep) at concentrations ranging from 2 mg/kg to 460 mg/kg, exceeding its HHSL of 0.15 mg/kg. Naphthalene was detected in two deep samples at concentrations ranging from 3.5 mg/kg to 390 mg/kg, exceeding its HHSL of 3.6 mg/kg in one sample.

4.1.3.2 Sediment Inorganic Compounds

Ten inorganic compounds (antimony, arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, silver, zinc) were detected in sediment samples at concentrations exceeding one or more screening level.

AVS/SEM analysis was performed on five sediment samples (four surface and one deep) collected from this exposure area. The SEM/AVS ratios calculated from the surface samples ranged from 0.040 to 0.15, all below 1. The SEM/AVS ratio for the deep sample was 0.16, also below 1. AVS/SEM results are presented in Table J-2 in Appendix J.

ESLs

Antimony was detected in three samples collected from the 0- to 6-inch interval at concentrations ranging from 1.3 mg/kg to 2.0 mg/kg, exceeding its ESL of 0.92 mg/kg. Antimony was detected in two samples collected from greater than 6-inches bgs at concentrations ranging from 1.3 mg/kg to 1.7 mg/kg, also exceeding its ESL of 0.92 mg/kg. Arsenic was detected in two samples collected from the 0- to 6-inch interval at concentrations ranging from 11.1 mg/kg to 26.3 mg/kg, exceeding its ESL of 9.79 mg/kg. Arsenic was detected in two samples collected from greater than 6-inches bgs at concentrations ranging

from 9.9 mg/kg to 11.5 mg/kg, also exceeding its ESL of 9.79 mg/kg. Beryllium was detected in six samples collected from the 0- to 6-inch interval at concentrations ranging from 1.1 mg/kg to 4.1 mg/kg, exceeding its ESL of 0.8 mg/kg. Beryllium was detected in two samples collected from greater than 6-inches bgs at concentrations ranging from 2.6 mg/kg to 3.3 mg/kg, also exceeding its ESL of 0.8 mg/kg. Cadmium was detected in four samples collected from the 0- to 6-inch interval at concentrations ranging from 1.4 mg/kg to 3.8 mg/kg, exceeding its ESL of 0.99 mg/kg. Cadmium was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 1.3 mg/kg to 2.5 mg/kg, also exceeding its ESL of 0.99 mg/kg. Chromium was detected in five samples collected from the 0- to 6-inch interval at concentrations ranging from 51.3 mg/kg to 105 mg/kg, exceeding its ESL of 43.4 mg/kg. Chromium was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 65.9 mg/kg to 83.6 mg/kg, also exceeding its ESL of 43.4 mg/kg. Copper was detected in five samples collected from the 0- to 6-inch interval at concentrations ranging from 32.7 mg/kg to 91.3 mg/kg, exceeding its ESL of 31.6 mg/kg. Copper was detected in three collected from greater than 6-inches bgs at concentrations ranging from 46.8 mg/kg to 72.0 mg/kg, also exceeding its ESL of 31.6 mg/kg. Mercury was detected in eight samples collected from the 0- to 6-inch interval at concentrations ranging from 0.20 mg/kg to 1.2 mg/kg, exceeding its ESL of 0.18 mg/kg. Mercury was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 0.38 mg/kg to 0.48 mg/kg, also exceeding its ESL of 0.18 mg/kg. Nickel was detected in five samples collected from the 0- to 6-inch interval at concentrations ranging from 29.4 mg/kg to 43.1 mg/kg, exceeding its ESL of 22.7 mg/kg. Silver was detected in eight samples collected from the 0- to 6-inch interval at concentrations ranging from 2.5 mg/kg to 32.6 mg/kg, exceeding its ESL of 0.5 mg/kg. Silver was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 4.2 mg/kg to 31.8 mg/kg, also exceeding its ESL of 0.5 mg/kg. Zinc was detected in five samples collected from the 0- to 6-inch interval at concentrations ranging from 153 mg/kg to 202 mg/kg, exceeding its ESL of 121 mg/kg. Zinc was detected in three samples collected from greater than 6-inches bgs at concentrations ranging from 184 mg/kg to 225 mg/kg, also exceeding its ESL of 121 mg/kg.

HHSLs

Arsenic was detected in all nine samples collected from the 0- to 6-inch interval at concentrations ranging from 5.2 mg/kg to 26.3 mg/kg, exceeding its HHSL of 0.39 mg/kg. Arsenic was detected in all three samples collected from greater than 6-inches bgs at concentrations ranging from 9.3 mg/kg to 11.5 mg/kg, also exceeding its HHSL of 0.39 mg/kg.

4.1.3.3 Surface Water SVOCs

One SVOC (bis(2-ethylhexyl)phthalate) was detected in surface water samples at concentrations exceeding one or more screening level.

ESLs

Bis(2-ethylhexyl)phthalate was detected in two surface water samples collected from two sample locations at concentrations ranging from 34 µg/L to 60 µg/L, exceeding its ESL of 8.4 µg/L.

HHSLs

Bis(2-ethylhexyl)phthalate was detected in two surface water samples collected from two sample locations at concentrations ranging from 34 µg/L to 60 µg/L, exceeding its HHSL of 6.0 µg/L.

4.1.3.4 Surface Water Inorganic Compounds

No inorganic compounds were detected at concentrations exceeding ESLs or HHSLs in this exposure area.

4.1.3.5 Fish and Invertebrate Samples

Fish Tissue

Five PAHs (benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, dibenzo[a,h]anthracene, and indeno[1,2,3-c,d]pyrene) were detected in fish tissue samples at concentrations exceeding their respective HHSLs. Benzo(a)pyrene was detected in 10 fish tissue samples at concentrations ranging from 0.00056 mg/kg to 0.0161 mg/kg, exceeding its HHSL of 0.00043 mg/kg. Benzo(a)anthracene was detected in six fish tissue samples at concentration ranging from 0.005 mg/kg to 0.0136 mg/kg, exceeding its HHSL of 0.0043 mg/kg. Benzo(b)fluoranthene was detected in five fish tissue samples at concentrations ranging from 0.0057 mg/kg to 0.0201 mg/kg, exceeding its HHSL of 0.0043 mg/kg. Dibenz(a,h)anthracene was detected in two fish tissue samples at concentrations of 0.00056 mg/kg to 0.012 mg/kg, exceeding its HHSL of 0.00043 mg/kg. Indeno(1,2,3-cd)pyrene was detected in one fish tissue sample at a concentration of 0.0043 mg/kg, equaling its HHSL of 0.0043 mg/kg.

One inorganic compound (arsenic) was detected in fish tissue samples at concentrations exceeding the HHSL. Arsenic was detected in 21 fish tissue samples at concentrations ranging from 0.027 mg/kg to 0.14 mg/kg, exceeding its HHSL of 0.0021 mg/kg.

Invertebrates

Seven PAHs (benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, and indeno[1,2,3-c,d]pyrene) were detected in invertebrate samples at concentrations exceeding the HHSLs. Benzo(a)pyrene was detected in five samples at concentrations ranging from 0.0644 mg/kg to 0.562 mg/kg, exceeding its HHSL of 0.00043 mg/kg. Benzo(a)anthracene was detected in five samples at concentrations ranging from 0.158 mg/kg to 1.09 mg/kg, exceeding its HHSL of 0.0043 mg/kg. Benzo(b)fluoranthene was detected in five samples at concentrations ranging from 0.112 mg/kg to 0.907 mg/kg, exceeding its HHSL of 0.0043 mg/kg. Benzo(k)fluoranthene was detected in five samples at concentrations ranging from 0.0565 mg/kg to 0.479 mg/kg, exceeding its HHSL of 0.043 mg/kg. Chrysene was detected in three samples at concentrations ranging from 0.612 mg/kg to 1.18 mg/kg, exceeding its HHSL of 0.43 mg/kg. Dibenzo(a,h)anthracene was detected in five samples at concentrations ranging from 0.01 mg/kg to 0.0967 mg/kg, exceeding its HHSL of 0.00043 mg/kg. Indeno(1,2,3-cd)pyrene was detected in five samples at concentrations ranging from 0.0192 mg/kg to 0.202 mg/kg, exceeding its HHSL of 0.0043 mg/kg.

Two inorganic compounds (arsenic and copper) were detected in invertebrate samples at concentrations exceeding the HHSLs. Arsenic was detected in five samples at concentrations ranging from 0.22 mg/kg to 0.46 mg/kg, exceeding its HHSL of 0.00321 mg/kg. Copper was detected in one sample at a concentration of 5.6 mg/kg, exceeding its HHSL of 5.4 mg/kg.

4.1.3.6 Low-Lying Surface Soil Samples

Twelve SVOCs (anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-c,d]pyrene, phenanthrene, and pyrene) were detected at concentrations exceeding one or more screening level in the four surface soil samples that were collected in this exposure area.

ESLs - SVOCs

Anthracene was detected in one sample at a concentration of 0.95 mg/kg, exceeding its ESL of 0.0572 mg/kg. Benzo(a)anthracene was detected in three samples at concentrations ranging from 0.21 mg/kg to 2 mg/kg, exceeding its ESL of 0.108 mg/kg. Benzo(a)pyrene was detected in three samples at concentrations ranging from 0.39 mg/kg to 3.3 mg/kg, exceeding its ESL of 0.15 mg/kg. Benzo(g,h,i)perylene was detected in two samples at concentrations ranging from 0.42 mg/kg to 3.1 mg/kg, exceeding its ESL of 0.17 mg/kg. Benzo(k)fluoranthene was detected in three samples at

concentrations ranging from 0.29 mg/kg to 2.4 mg/kg, exceeding its ESL of 0.24 mg/kg. Chrysene was detected in three samples at concentrations ranging from 0.36 mg/kg to 3.5 mg/kg, exceeding its ESL of 0.166 mg/kg. Dibenzo(a,h)anthracene was detected in two samples at concentrations ranging from 0.13 mg/kg to 0.94 mg/kg, exceeding its ESL of 0.033 mg/kg. Fluoranthene was detected in one sample at a concentration of 1.3 mg/kg, exceeding its ESL of 0.423 mg/kg. Fluorene was detected in one sample at a concentration of 0.13 mg/kg, exceeding its ESL of 0.0774 mg/kg. Indeno(1,2,3-cd)pyrene was detected in three samples at concentrations ranging from 0.2 mg/kg to 2.5 mg/kg, exceeding its ESL of 0.2 mg/kg. Phenanthrene was detected in one sample at a concentration of 0.52 mg/kg, exceeding its ESL of 0.204 mg/kg. Pyrene was detected in two samples at concentrations ranging from 0.21 mg/kg to 1.1 mg/kg, exceeding its ESL of 0.195 mg/kg.

The total PAH concentrations calculated for the three samples collected in this area that had concentrations of PAHs exceeding ESLs, ranged from 2.92 mg/kg to 25.799 mg/kg, all exceeding the total ESL PAH concentration of 1.61 mg/kg.

HHSLs - SVOCs

Benzo(a)anthracene was detected in three samples at concentrations ranging from 0.21 mg/kg to 2 mg/kg, exceeding its HHSL of 0.15 mg/kg. Benzo(a)pyrene was detected in three samples at concentrations ranging from 0.39 mg/kg to 3.3 mg/kg, exceeding its ESL of 0.015 mg/kg. Benzo(b)fluoranthene was detected in three samples at concentrations ranging from 0.46 mg/kg to 3.4 mg/kg, exceeding its HHSL of 0.15 mg/kg. Benzo(k)fluoranthene was detected in one sample at a concentration of 2.4 mg/kg, exceeding its HHSL of 1.5 mg/kg. Dibenzo(a,h)anthracene was detected in two samples at concentrations ranging from 0.13 mg/kg to 0.94 mg/kg, exceeding its HHSL of 0.015 mg/kg. Indeno(1,2,3-cd)pyrene was detected in three samples at concentrations ranging from 0.2 mg/kg to 2.5 mg/kg, exceeding its HHSL of 0.15 mg/kg.

Seven inorganic compounds (arsenic, beryllium, copper, nickel, silver, vanadium, and zinc) were detected at concentrations exceeding one or more screening level.

ESLs – Inorganic Compounds

Arsenic was detected in one sample at a concentration of 10.4 mg/kg, exceeding its ESL of 9.79 mg/kg. Beryllium was detected in all four samples at concentrations ranging from 3.7 mg/kg to 5.6 mg/kg, exceeding its ESL of 0.8 mg/kg. Copper was detected in all four samples at concentrations ranging from 35.0 mg/kg to 46.9 mg/kg, exceeding its ESL of 31.6 mg/kg. Nickel was detected in all four samples at

concentrations ranging from 36.6 mg/kg to 40.5 mg/kg, exceeding its ESL of 22.7 mg/kg. Silver was detected in all four samples at concentrations ranging from 7.2 mg/kg to 10.1 mg/kg, exceeding its ESL of 0.5 mg/kg. Vanadium was detected in three samples at concentrations ranging from 41.6 mg/kg to 52.1 mg/kg, exceeding its ESL of 40 mg/kg. Zinc was detected in all four samples at concentrations ranging from 147 mg/kg to 155 mg/kg, exceeding its ESL of 121 mg/kg.

HHSLs – Inorganic Compounds

Arsenic was detected in all four samples at concentrations ranging from 6.4 mg/kg to 10.4 mg/kg, exceeding its HHSL of 0.39 mg/kg.

4.1.3.7 Groundwater

No SVOCs were detected in groundwater samples at concentrations exceeding ESLs or HHSLs at either group of temporary monitoring wells located within the exposure area.

Sixteen inorganic compounds (aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, vanadium, and zinc) were detected in groundwater samples at concentrations exceeding one or more screening levels.

ESLs – Inorganic Compounds

Arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, vanadium, and zinc were detected at concentrations exceeding ESLs in temporary monitoring wells located at State Route 95. Arsenic was detected in two wells at concentrations ranging from 1,630 µg/L to 3,440 µg/L, exceeding its ESL of 150 µg/L. Barium was detected in four wells at concentrations ranging from 247 µg/L to 15,100 µg/L, exceeding its ESL of 220 µg/L. Beryllium was detected in one well at a concentration of 116 µg/L, exceeding its ESL of 11 µg/L. Cadmium was detected in one well at a concentration of 130 µg/L, exceeding its ESL of 2.5 µg/L. Chromium was detected in three wells at concentrations of 148 µg/L to 3,190 µg/L, exceeding its ESL of 86 µg/L. Cobalt was detected in four wells at concentrations ranging from 31.8 µg/L to 2,420 µg/L, exceeding its ESL of 24 µg/L. Copper was detected in five wells at concentrations ranging from 40.1 to 7,110 µg/L, exceeding its ESL of 9.3 µg/L. Lead was detected in five wells at concentrations ranging from 23.9 µg/L to 2,840 µg/L, exceeding its ESL of 6.4 µg/L. Mercury was detected in two wells at concentrations ranging from 2.0 µg/L to 3.7 µg/L, exceeding its ESL of 0.91 µg/L. Nickel was detected in four wells at concentrations ranging from 89.5 µg/L to 6,841 µg/L, exceeding its ESL of 52 µg/L. Selenium was detected in two wells at concentrations ranging from 6.6 µg/L to 149 µg/L, exceeding its ESL of 5 µg/L. Vanadium was detected

in five wells at concentrations ranging from 46.3 µg/L to 6,060 µg/L, exceeding its ESL of 44 µg/L. Zinc was detected in five wells at concentrations ranging from 127 µg/L to 19,400 µg/L, exceeding its ESL of 120 µg/L.

Lead was detected at one temporary monitoring well at Keener Pike, at a concentration of 7.0 µg/L, exceeding its ESL of 6.4 µg/L.

HHSLs – Inorganic Compounds

Aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, vanadium, and zinc were detected in temporary monitoring wells at State Route 95 at concentrations exceeding HHSLs. Aluminum was detected in four wells at concentrations ranging from 18,600 µg/L to 2,390,000 µg/L, exceeding its HHSL of 16,000 µg/L. Arsenic was detected in four wells at concentrations ranging from 35.1 µg/L to 3,440 µg/L, exceeding its HHSL of 10 µg/L. Barium was detected in two wells at concentrations ranging from 9,190 µg/L to 15,100 µg/L, exceeding its HHSL of 2,000 µg/L. Beryllium was detected in two wells at concentrations ranging from 5.5 µg/L to 130 µg/L, exceeding its HHSL of 45.0 µg/L. Cadmium was detected one well at a concentration of 130 µg/L, exceeding its HHSL of 5.0 µg/L. Chromium was detected in three wells at concentrations ranging from 148 µg/L to 3,190 µg/L, exceeding its HHSL of 100 µg/L. Cobalt was detected in five wells at concentrations ranging from 15.1 µg/L to 2,420 µg/L, exceeding its HHSL of 4.7 µg/L. Copper was detected in two wells at concentrations ranging from 3,150 µg/L to 7,110 µg/L, exceeding its HHSL of 1,300 µg/L. Iron was detected in five wells at concentrations ranging from 40,900 µg/L to 5,830,000 µg/L, exceeding its HHSL of 11,000 µg/L. Lead was detected in five samples at concentrations ranging from 23.9 µg/L to 2,840 µg/L, exceeding its HHSL of 15 µg/L. Manganese was detected in all six wells at concentrations ranging from 901 µg/L to 110,000 µg/L, exceeding its HHSL of 320 µg/L. Mercury was detected in two wells at concentrations ranging from 2.0 µg/L to 3.7 µg/L, exceeding its HHSL of 2.0 µg/L. Nickel was detected in two wells at concentrations ranging from 4,080 µg/L to 6,840 µg/L, exceeding its HHSL of 300 µg/L. Selenium was detected in one well at a concentration of 149 µg/L, exceeding its HHSL of 50 µg/L. Vanadium was detected in three wells at concentrations ranging from 239 µg/L to 6,060 µg/L, exceeding its HHSL of 78 µg/L. Zinc was detected in two wells at concentrations ranging from 8,190 µg/L to 19,400 µg/L, exceeding its HHSL of 4,700 µg/L.

Arsenic was the only inorganic compound detected in wells at Keener Pike above its HHSL. Two wells contained concentrations of arsenic ranging from 13.3 µg/L to 21.6 µg/L, exceeding its HHSL of 10 µg/L.

4.1.3.8 Exposure Area LSR-DWN2 Summary

Based on the analytical results for this exposure area, the following analytes were detected in various media exceeding one or more screening levels: 2-methylnaphthalene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, dibenzo(a,h)anthracene, dibenzofuran, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, phenanthrene, pyrene, aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, vanadium, and zinc.

Sediment

Analytes 2-methylnaphthalene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, dibenzofuran, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, naphthalene, phenanthrene, pyrene, antimony, arsenic, beryllium, cadmium, chromium, copper, mercury, nickel, silver, and zinc were detected in sediment samples at concentrations exceeding one or more screening levels. Of the analytes that exceeded sediment screening levels, the majority of SVOCs exceeded both ESLs and HHSLs at most locations. The majority of inorganic compounds exceeded ESLs.

Detections of PAHs at concentrations exceeding both ESLs and HHSLs are present throughout this entire exposure area at both surface locations and deeper locations. The highest total PAH concentration calculated for the surface sediments occurs at sample location LSR-SD-18 (3,096.00 mg/kg), which is located south of the former removal area. The highest total PAH concentration calculated for the deep sediments occur at sample location LSR-SD-16 (16,470.0 mg/kg). The total PAH concentration for the surface sample collected at location LSR-SD-16 is also elevated at 546.29 mg/kg. This sample is located just north of Keener Pike. The concentrations of PAHs greatly exceed the concentrations of PAHs detected in the upstream samples in LSR-UP1. The variation in PAH concentrations throughout the exposure area appears to be the result of flow restriction and subsequent sediment deposition from upstream contamination. These elevated concentrations also support the conclusion that historical discharges from BWC contaminated a larger portion of the LSR (beyond the area previously addressed in the removal action) and that contamination has remained in the LSR from those discharges.

Arsenic was the only inorganic compound that exceeded its HHSL at all surface and deep samples collected from this exposure area. However, concentrations of arsenic are similar to the concentrations detected in upstream samples collected in exposure area LSR-UP1, with the exception of LSR-SD-15,

where the arsenic concentration was 26.3 mg/kg, the highest concentration detected in the LSR. Concentrations of inorganic compounds were detected throughout this exposure area in both surface and deep sediment samples exceeding ESLs. Ratios for AVS/SEM results from five sediment samples collected from within this exposure area all were less than 1.

Surface Water

Bis(2-ethylhexyl)phthalate was detected in surface water samples collected from this exposure area at concentrations exceeding screening levels. This compound exceeded both ESLs and HHSLs.

Bis(2-ethylhexyl)phthalate was detected at two surface water sample locations, LSR-SW-14 and LSR-SW-19. At both locations, the concentrations, 60 µg/L and 34 µg/L, exceeded the ESL of 8.4 µg/L as well as the HHSL, which is the MCL of 6.0 µg/L. Bis(2-ethylhexyl)phthalate was not detected in sediment samples at either of these two locations. It was also not detected in upstream locations within exposure area LSR-UP1.

No SVOCs were detected at concentrations exceeding ESLs or HHSLs in this exposure area, indicating that PAHs detected in the sediments in this exposure area are most likely immobile or at least are not migrating to surface water.

No inorganic compounds were detected in surface water samples collected from within this exposure area at concentrations exceeding ESLs or HHSLs. The lack of inorganic compounds at concentrations exceeding ESLs or HHSLs indicates that inorganic compounds detected in sediments in this exposure area are also not migrating to the surface water.

Fish Tissue and Invertebrate

Fish Tissue

PAHs benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene were detected in 11 fish tissue samples at concentrations exceeding HHSLs collected from this exposure area. Of the 11 fish tissue samples, results above screening levels were detected in four fillet samples and seven carcass samples. In general, concentrations of PAHs detected in fish tissues samples in this area were higher than those detected in exposure area LSR-DWN1.

Arsenic was detected above its HHSL in all fish tissue samples collected within this exposure area.

The detected PAHs and arsenic were also detected in sediments in this exposure area.

Invertebrate

PAHs benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene were detected in five invertebrate samples at concentrations above HHSLs collected in this exposure area.

Arsenic and copper were detected in invertebrate samples exceeding their HHSLs in this exposure area. Copper slightly exceeded its HHSL of 5.4 mg/kg. Arsenic exceeded its HHSL in all five invertebrate samples collected within the exposure area.

The detected PAHs and inorganic compounds were also detected in sediments in this exposure area. When compared with the invertebrate sample collected upstream in exposure area LSR-UP1, the concentrations of arsenic are actually less in this exposure area than in the upstream sample, at 0.55 mg/kg. With regards to PAHs, only three PAH compounds were detected in the upstream sample (LSR-IT-03). In general, the concentrations of PAHs detected in invertebrates collected within this exposure area are substantially higher than those detected in the upstream sample.

Low-Lying Surface Soils

Analytes anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, phenanthrene, pyrene, arsenic, beryllium, copper, nickel, silver, vanadium, and zinc were detected in surface soil samples at concentrations exceeding one or more screening levels. Of the SVOCs that exceeded surface soil screening levels, the majority exceeded both their ESL and HHSL. Of the inorganic compounds that exceeded their screening levels, the majority exceeded ESLs.

Of the four surface soil samples collected within the exposure area, one location (LSR-SS-06) did not contain any SVOCs at concentrations exceeding screening levels. The total PAH concentrations calculated for the three locations with SVOC results above screening levels ranged from 2.92 mg/kg to 25.799 mg/kg, exceeding the total ESL PAH concentration of 1.61 mg/kg. The highest total PAH concentration was calculated at location LSR-SS-05, which is located just south of Keener Pike. This location is downstream of the highest concentrations of PAHs detected in sediments.

With the exception of vanadium, the other inorganic compounds were detected in all of the surface soil samples at concentrations exceeding mainly the ESLs. Vanadium was not detected above a screening level at sample location LSR-SS-05.

The PAHs and inorganic compounds detected in the surface soil samples within this exposure area are similar to those detected in the sediments within this exposure area.

Groundwater

Aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, silver, vanadium, and zinc were detected in temporary monitoring wells located within this exposure area at concentrations exceeding screening levels. Of the analytes that exceeded groundwater screening levels, the majority was located at State Route 95 and exceeded HHSLs.

No SVOCs were detected at concentrations exceeding ESLs or HHSLs in this exposure area at either group of temporary monitoring wells. PAHs were detected in both surface and deep sediments in this exposure area but not in the groundwater samples, which indicates that contaminants from surface and deep sediments are not migrating outward to the shallow aquifer.

The group of temporary monitoring wells at Keener Pike contained arsenic and lead. Lead was detected slightly above its ESL but was below its HHSL, which is the MCL of 15 µg/L. Arsenic was detected at concentrations exceeding its MCL of 10 µg/L at two samples at Keener Pike. These two samples are in the same area as the elevated concentration of arsenic detected in sediment at location LSR-SD-15.

The group of temporary monitoring wells at State Route 95 contained numerous inorganic chemicals exceeding screening levels. One temporary well, LSR-TW-15S, was screened more shallow than the other four temporary wells in that area, and the shallow well did not exhibit the same concentrations and number of inorganic compounds, indicating that the contamination is deeper than 16 feet bgs. Sediment samples closest to this group of temporary wells (LSR-SD-18 and LSR-SD-19) contained inorganic compounds but generally at lower concentrations and fewer inorganic compounds present in the groundwater, indicating groundwater detections are not caused when inorganic compounds in the sediment leach to groundwater. In addition, a landfill exists east of the LSR at this location. Because these inorganic compounds were not seen in the other temporary well groups at similar concentrations or nearby sediment samples at extremely elevated levels, it is believed the inorganic contamination in the groundwater is not attributed to LSR.

4.1.4 Extent of Contamination – Exposure Area LSR-DWN3

A total of 12 sediment and 10 surface water samples, not including duplicate samples, were collected from 10 sample locations within a 2.5-mile stretch of the LSR, downstream of the historically visually affected area of the LSR. The sediment and surface water samples were collected to delineate the nature and extent of impacts relative to established screening levels. A sediment sample was collected from 0- to 6-inches bgs at all 10 sample locations. A deeper sediment sample was collected at two sample locations (LSR-SD-01 and LSR-SD-10) for SVOC analysis based on the visual presence of possible creosote contamination. A deeper sediment sample was collected at two sample locations (LSR-SD-05 and LSR-SD-10) for analysis of inorganic compounds. Each sediment and surface water sample was analyzed for TCL SVOCs, TAL metals, mercury, cyanide, and TOC. One of the sediment samples was also analyzed for AVS/SEM. Surface water samples were also analyzed for hardness.

In addition, 18 fish tissue samples (nine fillet and nine carcass) and three invertebrate samples were collected from this exposure area and analyzed for PAHs (by EPA Method 8270-SIM), TAL metals, and percent lipids.

Three surface soil samples collected from four sample locations from low-lying areas adjacent to the LSR were also collected from this exposure area. The surface soil samples were collected to evaluate potential contamination from sediment deposition when the river overflows its banks during high water. The surface soil samples were analyzed for TCL SVOCs, TAL metals, mercury, and cyanide.

A total of four groundwater samples were collected from four temporary monitoring wells located near State Route 739. The groundwater samples were collected to assess whether shallow groundwater is being contaminated by LSR sediments. The groundwater samples were analyzed for TCL VOCs, TCL SVOCs, TAL metals, mercury, and cyanide.

Figure 37 presents all sample locations within Exposure Area LSR-DWN3 that exceeded one or more established screening levels.

4.1.4.1 Sediment SVOCs

Thirteen SVOCs (anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene,

indeno[1,2,3-c,d]pyrene, phenanthrene, and pyrene) were detected in sediment samples at concentrations exceeding one or more screening levels.

ESLs

Anthracene was detected in eight sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.15 mg/kg to 4.8 mg/kg, exceeding its ESL of 0.0572 mg/kg. Anthracene was detected in two sediment samples collected from greater than 6 inches bgs at concentrations ranging from 0.24 mg/kg to 0.54 mg/kg, also exceeding its ESL of 0.0572 mg/kg. Benzo(a)anthracene was detected in all 10 sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.11 mg/kg to 14 mg/kg, exceeding its ESL of 0.108 mg/kg. Benzo(a)anthracene was detected in two sediment samples collected from greater than 6 inches bgs at concentrations ranging from 0.85 mg/kg to 3.9 mg/kg, also exceeding its ESL of 0.108 mg/kg. Benzo(a)pyrene was detected in eight sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.34 mg/kg to 13 mg/kg, exceeding its ESL of 0.15 mg/kg. Benzo(a)pyrene was detected in two sediment samples collected from greater than 6 inches bgs at concentrations ranging from 0.84 mg/kg to 3.7 mg/kg, also exceeding its ESL. Benzo(b)fluoranthene was detected in one sediment sample collected from 0- to 6-inches bgs at a concentration of 14 mg/kg, exceeding its ESL of 10.4 mg/kg. Benzo(g,h,i)perylene was detected in eight sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.3 mg/kg to 9.1 mg/kg, exceeding its ESL of 0.17 mg/kg. Benzo(g,h,i)perylene was detected in two sediment samples collected from greater than 6-inches bgs at concentrations ranging from 0.64 mg/kg to 2.4 mg/kg, also exceeding its ESL of 0.17 mg/kg. Benzo(k)fluoranthene was detected in seven sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.31 mg/kg to 10 mg/kg, exceeding its ESL of 0.24 mg/kg. Benzo (k)fluoranthene was detected in two sediment samples collected from greater than 6-inches bgs at concentrations ranging from 0.59 mg/kg to 3.9 mg/kg, also exceeding its ESL of 0.24 mg/kg. Chrysene was detected in nine sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.17 mg/kg to 17 mg/kg, exceeding its ESL of 0.166 mg/kg. Chrysene was detected in two sediment samples collected from greater than 6-inches bgs at concentrations ranging from 1.1 mg/kg to 4.6 mg/kg, also exceeding its ESL of 0.166 mg/kg. Dibenzo(a,h)anthracene was detected in seven sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.1 mg/kg to 4 mg/kg, exceeding its ESL of 0.033 mg/kg. Dibenzo(a,h)anthracene was detected in one sediment samples collected from greater than 6 inches bgs at a concentrations of 0.79 mg/kg, also exceeding its ESL of 0.033 mg/kg. Fluoranthene was detected in seven sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.95 mg/kg to 41 mg/kg, exceeding its ESL of 0.423 mg/kg. Fluoranthene was detected in two sediment samples collected from greater than 6-inches bgs at concentrations ranging from 1.6 mg/kg

to 13 mg/kg, also exceeding its ESL of 0.423 mg/kg. Fluorine was detected in four sediment samples collected from 0- to 6-inches bgs at concentrations ranging from 0.12 mg/kg to 1.30 mg/kg, exceeding its ESL of 0.0771 mg/kg. Fluorene was detected in one sediment sample collected from greater than 6-inches bgs at a concentration of 2.5 mg/kg, also exceeding its ESL of 0.0771 mg/kg. Indeno(1,2,3-c,d)pyrene was detected in eight sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.24 mg/kg to 7.9 mg/kg, exceeding its ESL of 0.2 mg/kg. Indeno(1,2,3-cd)pyrene was detected in two sediment samples collected from greater than 6 inches bgs at concentrations ranging from 0.5 mg/kg to 2 mg/kg, also exceeding its ESL of 0.2 mg/kg. Phenanthrene was detected in five sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.27 mg/kg to 2.20 mg/kg, exceeding its ESL of 0.204 mg/kg. Phenanthrene was detected in two sediment samples collected from greater than 6-inches bgs at concentrations ranging from 0.22 mg/kg to 0.58 mg/kg, also exceeding its ESL of 0.204 mg/kg. Pyrene was detected in 10 sediment samples collected from 0- to 6-inches bgs at concentration ranging from 0.29 mg/kg to 29 mg/kg, exceeding its ESL of 0.1958 mg/kg. Pyrene was detected in two sediment samples collected from greater than 6-inches bgs at concentrations ranging from 2.4 mg/kg to 9.8 mg/kg, exceeding its ESL of 0.1958 mg/kg.

Total PAH concentrations for the 10 surface sediment samples collected in this exposure area were calculated and ranged from 1.35 mg/kg to 114.34 mg/kg. Eight of the surface sediment samples exceeded the total ESL PAH concentration of 1.61 mg/kg. Total PAH concentrations for the two deep sediment samples collected in this exposure area were calculated and ranged from 10.19 mg/kg to 13.53 mg/kg, both exceeding the total ESL PAH concentration of 1.61 mg/kg. In the two sample locations where a surface and deep sediment sample was collected, both the surface total PAH concentration and deep total PAH contraction exceeded the total ESL PAH concentration.

HHSLs

Benzo(a)anthracene was detected in all 12 sediment samples (10 surface and two deep) at a concentration ranging from 0.34 mg/kg to 14 mg/kg, exceeding its HHSL of 0.15 mg/kg. Benzo(a)pyrene was detected in 11 sediment samples (nine surface and two deep) at concentrations ranging from 0.12 mg/kg to 13 mg/kg, exceeding its HHSL of 0.015 mg/kg. Benzo(b)fluoranthene was detected in 10 sediment samples (eight surface and two deep) at concentrations ranging from 0.25 mg to 14 mg/kg, exceeding its HHSL of 0.15 mg/kg. Benzo(k)fluoranthene was detected in three sediment samples (two surface and one deep) at concentrations ranging from 1.6 mg/kg to 10 mg/kg, exceeding its HHSL of 1.5 mg/kg. Chrysene was detected in two surface sediment samples at concentrations of 16 mg/kg and 17 mg/kg, exceeding its HHSL of 15 mg/kg. Dibenzo(a,h)anthracene was detected in eight sediment samples (seven surface and

one deep) at concentrations ranging from 0.1 mg/kg to 4 mg/kg, exceeding its HHSL of 0.015 mg/kg. Indeno(1,2,3-c,d)pyrene was detected in 10 sediment samples (eight surface and two deep) at concentrations ranging from 0.16 mg/kg to 7.9 mg/kg, exceeding its HHSL of 0.15 mg/kg.

4.1.4.2 Sediment Inorganic Compounds

Eight inorganic compounds (antimony, arsenic, cadmium, copper, mercury, nickel, silver, and zinc) were detected in sediment samples at concentrations exceeding one or more screening level. AVS/SEM analysis was performed on one sediment sample (surface) collected from this exposure area. The SEM/AVS ratio calculated for this sample was less than 1. AVS/SEM results are presented in Table J-2 in Appendix J.

ESLs

Antimony was detected in two sediment samples (surface) at concentrations of 1.3 mg/kg and 8.3 mg/kg, exceeding its ESL of 0.92 mg/kg. Arsenic was detected three sediment samples (two surface and one deep) at concentrations ranging from 11.5 mg/kg to 23.5 mg/kg, exceeding its ESL of 9.79 mg/kg. Cadmium was detected in three sediment samples (two surface and one deep) at concentrations ranging from 2.5 mg/kg to 8.5 mg/kg, exceeding its ESL of 0.99 mg/kg. Copper was detected in three sediment samples (two surface and one deep) at concentrations ranging from 32.1 mg/kg to 57.7 mg/kg, exceeding its ESL of 31.6 mg/kg. Mercury was detected at three sediment samples (two surface and one deep) at concentrations ranging from 0.36 mg/kg to 1.2 mg/kg, exceeding its ESL of 0.18 mg/kg. Nickel was detected in four sediment samples (three surface and one deep) at concentrations ranging from 25.8 mg/kg to 46.7 mg/kg, exceeding its ESL of 22.7 mg/kg. Silver was detected in all 12 sediment samples (10 surface and two deep) at concentrations ranging from 4.4 mg/kg to 31.8 mg/kg, exceeding its ESL of 0.5 mg/kg. Zinc was detected in three sediment samples (two surface and one deep) at concentrations ranging from 141 mg/kg to 190 mg/kg.

HHSLs

Arsenic was detected in all 12 sediment samples (10 surface and two deep) at concentrations ranging from 4.8 mg/kg to 23.5 mg/kg, exceeding its HHSL of 0.39 mg/kg.

4.1.4.3 Surface Water SVOCs

Indeno(1,2,3-c,d)pyrene was detected in one surface water sample (LSR-SW-07) at a concentration of 2.5 µg/L, exceeding its HHSL of 0.029 µg/L.

4.1.4.4 Surface Water Inorganic Compounds

Arsenic, cyanide, and thallium were detected at concentrations exceeding one or more screening level.

ESLs

Cyanide was detected in seven surface water samples at concentrations ranging from 5.2 µg/L to 10.2 µg/L, exceeding its ESL of 5.2 µg/L. Cyanide did not exceed the MCL at any sample location.

HHSLs

Arsenic was detected in one surface water sample at a concentration of 10.6 µg/L, exceeding its HHSL of 10 µg/L, which is the MCL for arsenic. Thallium was detected in four surface water samples at concentrations ranging from 5.4 µg/L to 8.7 µg/L, exceeding its HHSL of 2.0 µg/L, which is also the MCL for thallium.

4.1.4.5 Fish and Invertebrate Samples

Fish Tissue

Four PAHs (benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, and dibenzo[a,h]anthracene) were detected in fish tissue samples at concentrations exceeding their respective HHSL. Benzo(a)pyrene was detected in 7 fish tissue samples at concentrations ranging from 0.00052 mg/kg to 0.0092 mg/kg, exceeding its HHSL of 0.00043 mg/kg. Benzo(a)anthracene was detected in five fish tissue samples at concentrations ranging from 0.006 mg/kg to 0.0114 mg/kg, exceeding its HHSL of 0.0043 mg/kg. Benzo(b)fluoranthene was detected in two fish tissue samples at concentrations ranging from 0.0048 mg/kg to 0.014 mg/kg, exceeding its HHSL of 0.0043 mg/kg. Dibenz(a,h)anthracene was detected in two fish tissue samples at concentrations ranging from 0.00053 mg/kg to 0.0013 mg/kg, exceeding its HHSL of 0.00043 mg/kg.

One inorganic compound (arsenic) was detected in 10 fish tissue samples at concentrations ranging from 0.030 mg/kg to 0.070 mg/kg, exceeding its HHSL of 0.0021 mg/kg.

Invertebrate

Seven PAHs (benzo[a]pyrene, benzo[a]anthracene, benzo[b]fluoranthene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, and indeno[1,2,3-c,d]pyrene) were detected in invertebrate samples at concentrations exceeding HHSLs. Benzo(a)pyrene was detected in all three samples at concentrations ranging from 0.0924 mg/kg to 0.503 mg/kg, exceeding its HHSL of 0.00043 mg/kg. Benzo(a)anthracene was detected in all three samples at concentrations ranging from 0.176 mg/kg to 0.842 mg/kg, exceeding its HHSL of 0.0043 mg/kg. Benzo(b)fluoranthene was detected in all three samples at concentrations ranging from 0.139 mg/kg to 0.739 mg/kg, exceeding its HHSL of 0.0043 mg/kg. Benzo(k)fluoranthene was detected in all three samples at concentrations ranging from 0.0967 mg/kg to 0.465 mg/kg, exceeding its HHSL of 0.043 mg/kg. Chrysene was detected in one sample at a concentration of 0.965 mg/kg, exceeding its HHSL of 0.43 mg/kg. Dibenzo(a,h)anthracene was detected in all three samples at concentrations ranging from 0.0219 mg/kg to 0.0894 mg/kg, exceeding its HHSL of 0.00043 mg/kg. Indeno(1,2,3-cd)pyrene was detected in all three samples at concentrations ranging from 0.0333 mg/kg to 0.259 mg/kg, exceeding its HHSL of 0.0043 mg/kg.

Four inorganic compounds (arsenic, cobalt, copper, and iron) were detected in invertebrate samples at concentrations exceeding HHSLs. Arsenic was detected in all three samples at concentrations ranging from 0.33 mg/kg to 1.6 mg/kg, exceeding its HHSL of 0.0021 mg/kg. Cobalt was detected in one sample at a concentration of 1.5 mg/kg, exceeding its HHSL of 0.41 mg/kg. Copper was detected in two samples at concentrations ranging from 5.5 mg/kg to 6.7 mg/kg, exceeding its HHSL of 5.4 mg/kg. Iron was detected in one sample at a concentration of 3,070 mg/kg, exceeding its HHSL of 950 mg/kg.

4.1.4.6 Low-Lying Surface Soil Samples

SVOCs

Thirteen SVOCs (anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-c,d]pyrene, phenanthrene, and pyrene) were detected at concentrations exceeding one or more screening levels.

ESLs – SVOCs

Anthracene was detected in one sample at a concentration of 0.24 mg/kg, exceeding its ESL of 0.0572 mg/kg. Benzo(a)anthracene was detected in one sample at a concentration of 0.2 mg/kg, exceeding its ESL of 0.108 mg/kg. Benzo(a)pyrene was detected at one sample at a concentration of 0.35 mg/kg, exceeding its ESL of 0.15 mg/kg. Benzo(g,h,i)perylene was detected in one sample at a concentration of

0.37 mg/kg, exceeding its ESL of 0.17 mg/kg. Benzo(k)fluoranthene was detected in one sample at a concentration of 0.27 mg/kg, exceeding its ESL of 0.24 mg/kg. Chrysene was detected in all three samples at concentrations ranging from 0.19 mg/kg to 0.36 mg/kg, exceeding its ESL of 0.166 mg/kg. Dibenzo(a,h)anthracene was detected in one sample at a concentration of 0.1 mg/kg, exceeding its ESL of 0.033 mg/kg. Fluoranthene was detected in one sample at a concentration of 0.48 mg/kg, exceeding its ESL of 0.423 mg/kg. Fluorene was detected in one sample at a concentration of 0.21 mg/kg, exceeding its ESL of 0.0774 mg/kg. Indeno(1,2,3-cd)pyrene was detected in one sample at a concentration of 0.29 mg/kg, exceeding its ESL of 0.2 mg/kg. Phenanthrene was detected in one sample at a concentration of 0.83 mg/kg, exceeding its ESL of 0.204 mg/kg. Pyrene was detected in two samples at concentrations of 0.2 mg/kg and 0.39 mg/kg, exceeding its ESL of 0.195 mg/kg.

Total PAH concentrations were calculated for all three samples collected from this exposure area, and concentrations ranged from 0.87 mg/kg to 2.778 mg/kg. In two of the three samples, the total PAH concentration exceeded the total ESL PAH concentration of 1.61 mg/kg.

HHSLs – SVOCs

Benzo(a)anthracene was detected in one sample at a concentration 0.2 mg/kg, exceeding its HHSL of 0.15 mg/kg. Benzo(a)pyrene was detected in two samples at concentrations of 0.15 mg/kg and 0.35 mg/kg, exceeding its HHSL of 0.015 mg/kg. Benzo(b)fluoranthene was detected in one sample at a concentration of 0.36 mg/kg, exceeding its HHSL of 0.36 mg/kg. Dibenzo(a,h)anthracene was detected in one sample at a concentration of 0.1 mg/kg, exceeding its HHSL of 0.015 mg/kg. Indeno(1,2,3-cd)pyrene was detected in one sample at a concentration 0.29 mg/kg, exceeding its HHSL of 0.15 mg/kg.

Inorganic Compounds

Eleven inorganic compounds (aluminum, antimony, arsenic, beryllium, chromium, copper, mercury, nickel, silver, vanadium, and zinc) were detected at concentrations exceeding one or more screening levels.

ESLs - Inorganics

Aluminum was detected in one sample at a concentration of 39,400 mg/kg, exceeding its ESL of 39,000 mg/kg. Antimony was detected in one sample at a concentration of 2.1 mg/kg, exceeding its ESL of 0.92 mg/kg. Arsenic was detected in two samples at concentrations ranging from 10.3 mg/kg to 12.2 mg/kg, exceeding its ESL of 9.79 mg/kg. Beryllium was detected in three samples at concentrations ranging from 1.6 mg/kg to 10.6 mg/kg, exceeding its ESL of 0.8 mg/kg. Chromium was detected in two samples

at concentrations ranging from 43.5 mg/kg to 47.5 mg/kg, exceeding its ESL of 43.4 mg/kg. Copper was detected in all three samples at concentrations ranging from 42.7 mg/kg to 49.0 mg/kg, exceeding its ESL of 31.6 mg/kg. Mercury was detected in one sample at a concentration of 0.19 mg/kg, exceeding its ESL of 0.18 mg/kg. Nickel was detected in all three samples at concentrations ranging from 35.4 mg/kg to 47.5 mg/kg, exceeding its ESL of 22.7 mg/kg. Silver was detected in all three samples at concentrations ranging from 7.4 mg/kg to 12.2 mg/kg, exceeding its ESL of 0.5 mg/kg. Vanadium was detected in two samples at concentrations ranging from 41.4 mg/kg to 58.9 mg/kg, exceeding its ESL of 40 mg/kg. Zinc was detected in three samples at concentrations ranging from 185 mg/kg to 211 mg/kg, exceeding its ESL of 121 mg/kg.

HHSLs – Inorganic Compounds

Arsenic was detected in all three samples at concentrations ranging from 8.9 mg/kg to 12.2 mg/kg, exceeding its HHSL of 0.39 mg/kg.

4.1.47 Groundwater

No SVOCs or inorganic compounds were detected at concentrations above ESLs or HHSLs from temporary monitoring wells in this exposure area.

4.1.4.8 Exposure Area LSR-DWN3 Summary

Based on the analytical results for this exposure area, the following analytes were detected in various media exceeding one or more screening levels: anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, phenanthrene, pyrene, aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, cyanide, mercury, nickel, silver, thallium, vanadium, and zinc.

Sediment

Anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, phenanthrene, pyrene, antimony, arsenic, cadmium, copper, mercury, nickel, silver, and zinc were detected in sediment samples at concentrations exceeding one or more screening level. Of the SVOCs that exceeded sediment screening levels, the majority exceeded ESLs. Of the inorganic compounds that exceeded sediment screening levels, the majority exceeded ESLs.

The highest total PAH concentration calculated in surface sediments in this exposure area occurred at location LSR-SD-01, with a total PAH concentration of 114.34 mg/kg. This location is just north of the confluence with the Scioto River. However, the total PAH concentration calculated in the surface sediment sample LSR-SD-02, located approximately 415 feet upstream of LSR-SD-01, was only 1.35 mg/kg, which is significantly lower than the total at LSR-SD-01. The deep sediment sample at LSR-SD-01 also exceeded the total ESL PAH concentration, with a total PAH concentration of 10.19 mg/kg, indicating that the PAH contamination exists to at least 18 inches bgs. These results indicate that either a source (surface runoff or discharge) exists between the two sample locations or that depositional variability exists where LSR-SD-01 is situated in a high deposition area and subject to deposition by upstream contamination.

In addition, elevated concentrations of PAHs were also detected north of sample location LSR-SD-03 to exposure area LSR-DWN2. Although total PAH concentrations in this section of the exposure area are less than those in exposure area LSR-DWN2, the eight sediment samples (seven surface and one deep) all exceed the total ESL PAH concentration. The variation in PAH concentrations throughout the area appears to be the result of flow restriction (and subsequent sediment deposition) from upstream contamination.

Less inorganic contamination was detected in this exposure area when compared with the exposure areas LSR-DWN1 and LSR-DWN2; however, arsenic was still detected in all samples (surface and deep) at concentrations exceeding mainly HHSLs. Silver was also detected in all samples at concentrations exceeding ESLs. However, when compared with the upstream locations in LSR-UP1, the concentrations are comparable for both arsenic and silver.

AVS/SEM results from the one sediment sample collected from within this exposure area show a SEM/AVS ratio of less than 1, specifically 0.89.

Surface Water

Indeno(1,2,3-cd)pyrene was detected in one surface water sample at sample location (LSR-SW-07, exceeding its HHSL. This PAH was also detected in the sediment at this location; however, other PAHs were also detected in sediments at that sample location and within the exposure area that were not detected in any surface water locations, however, turbulence in the surface water sample could account for this result because on the whole, SVOCs in the LSR sediment remain in the sediment..

Arsenic was detected above its MCL at one sample location, LSR-SW-04, within the exposure area. Thallium was detected in four samples, all exceeding the MCL of 2 µg/L. It is not known where thallium originates from because it was not detected in any other surface water samples as well as any sediment samples. Cyanide was also detected in six surface water samples, all located north of sample location LSR-SW-03. Cyanide was not detected in any other exposure areas along LSR.

Fish Tissue and Invertebrate

Fish Tissue

PAHs benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene were detected in 13 fish tissue samples at concentrations exceeding HHSLs collected from this exposure area. Of the 13 fish tissue samples, results above screening levels were detected in five fillet samples and eight carcass samples. In general, concentrations of PAHs detected in fish tissues samples in this area were much less than were detected in exposure area LSR-DWN2, just upstream.

Arsenic was detected above its HHSL in 15 of 18 fish tissue samples collected within this exposure area. Of the 15 fish tissue samples, results above screening levels were detected in seven fillet and eight carcass samples.

The detected PAHs and arsenic were also detected in sediments in this exposure area..

Invertebrate

PAHs benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene were detected in three invertebrate samples at concentrations above HHSLs collected in this exposure area.

Arsenic and copper were detected in invertebrate samples exceeding the HHSLs in this exposure area. Copper slightly exceeded its HHSL of 5.4 mg/kg at the two locations, with concentrations of 5.5 mg/kg and 6.7 mg/kg. Arsenic exceeded its HHSL in all three invertebrate samples collected within the exposure area.

The detected PAHs and inorganic compounds were also detected in sediments in this exposure area as well and could indicate that the invertebrates are ingesting the compounds. When compared with the

invertebrate sample collected upstream in exposure area LSR-UP1, the concentrations of arsenic are actually less in this exposure area than in the upstream sample, with a concentration of 0.55 mg/kg. With regards to PAHs, only three PAH compounds were detected in the upstream sample (LSR-IT-03). In general, the concentrations detected in invertebrates collected within this exposure are substantially higher than those detected in the upstream sample.

Low-Lying Surface Soils

Anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, phenanthrene, pyrene, aluminum, antimony, arsenic, beryllium, chromium, copper, mercury, nickel, silver, vanadium, and zinc were detected in surface soil samples at concentrations exceeding one more screening levels. Of the SVOCs that exceeded surface soil screening levels, the majority exceeded ESLs. Of the inorganic compounds that exceeded their screening levels, the majority exceeded ESLs.

Of the three surface soil samples collected within the exposure area, one location (LSR-SS-03) exhibited the highest concentration of PAHs, with a total PAH concentration calculated at 2.778 mg/kg. This surface soil sample is located within the stretch of this exposure area where sediment concentrations of PAHs were also elevated compared with the downstream stretch. The total PAH concentration calculated for the most downgradient sample, sample location LSR-SS-01, was 0.87 mg/kg, below the total ESL PAH concentration of 1.614 mg/kg.

Inorganic compounds detected in all of the surface soil samples were at concentrations exceeding mainly ESLs.

The PAHs and inorganic compounds detected in the surface soil samples within this exposure area are similar to those detected in the sediments within this exposure area.

Groundwater

No SVOCs or inorganic compounds were detected at concentrations exceeding ESLs or HHSLs in this exposure area. PAHs were detected in both surface and deep sediments in this exposure area but not in the groundwater samples, which indicates that contaminants from surface and deep sediments are not migrating outward to the shallow aquifer.

4.1.5 Extent of Contamination – Exposure Area LSR-DWN4

A total of four sediment and surface water samples were collected from four locations from within the nearby waterways (Columbia Ditch and Rockswale Ditch) that connect with the LSR. The samples were collected to evaluate possible alternate upstream sources of contamination. All sediment samples in this exposure area were collected from 0- to 6-inches bgs. Each sediment and surface water sample was analyzed for TCL SVOCs, TAL metals, mercury, and cyanide. Sediment was also analyzed for TOC. Surface water samples were also analyzed for hardness.

Figure 38 presents all sample locations within Exposure Area LSR-DWN4 that exceeded one or more established screening levels.

4.1.5.1 Sediment SVOCs

Thirteen SVOCs (3,3'-dichlorobenzidine, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenzo[a,h]anthracene, fluoranthene, fluorene, indeno[1,2,3-c,d]pyrene, phenanthrene, and pyrene) were detected at concentrations exceeding one or more screening level.

3,3'-Dichlorobenzidine was detected at one sediment location at a concentration of 0.23 mg/kg, exceeding its ESL of 0.127 mg/kg. Anthracene was detected in all four sediment samples at concentrations ranging from 0.14 mg/kg to 0.49 mg/kg, exceeding its ESL of 0.0572 mg/kg. Benzo(a)anthracene was detected in all four samples at concentrations ranging from 0.74 mg/kg to 4.60 mg/kg, exceeding its ESL of 0.108 mg/kg. Benzo(a)pyrene was detected in all four samples at concentrations ranging from 0.64 mg/kg to 1.30 mg/kg, exceeding its ESL of 0.15 mg/kg. Benzo(g,h,i)perylene was detected in all four samples at concentrations ranging from 0.39 mg/kg to 0.52 mg/kg, exceeding its ESL of 0.17 mg/kg.

Benzo(k)fluoranthene was detected in all four samples at concentrations ranging from 0.65 mg/kg to 1.40 mg/kg, exceeding its ESL of 0.24 mg/kg. Chrysene was detected in all four samples at concentrations ranging from 0.96 mg/kg to 7.50 mg/kg, exceeding its ESL of 0.166 mg/kg. Dibenzo(a,h)anthracene was detected in all four samples at concentrations ranging from 0.13 mg/kg to 0.18 mg/kg, exceeding its ESL of 0.033 mg/kg. Fluoranthene was detected in all four samples at concentrations ranging from 1.10 mg/kg to 6.30 mg/kg, exceeding its ESL of 0.423 mg/kg. Fluorene was detected in three samples at concentrations ranging from 0.14 mg/kg to 0.22 mg/kg, exceeding its ESL of 0.0774 mg/kg.

Indeno(1,2,3-cde)pyrene was detected in all four samples at concentrations ranging from 0.32 mg/kg to 0.55 mg/kg, exceeding its ESL of 0.2 mg/kg. Phenanthrene was detected in all four samples at

concentrations ranging from 0.60 mg/kg to 1.30 mg/kg, exceeding its ESL of 0.204 mg/kg. Pyrene was detected in three samples at concentrations ranging from 1.70 mg/kg to 4.90 mg/kg, exceeding its ESL of 0.195 mg/kg.

Total PAH concentrations were calculated for the four sediment samples collected from this exposure area. Concentrations ranged from 7.38 mg/kg to 30.75 mg/kg, with the highest total PAH concentration located just north of the confluence with the LSR. All four total PAH concentrations exceeded the total ESL PAH concentration of 1.61 mg/kg.

HHSLs

Benzo(a)anthracene was detected in all four samples at concentrations ranging from 0.74 mg/kg to 4.60 mg/kg, exceeding its ESL of 0.15 mg/kg. Benzo(a)pyrene was detected in all four samples at concentrations ranging from 0.64 mg/kg to 1.30 mg/kg, exceeding its ESL of 0.015 mg/kg.

Benzo(b)fluoranthene was detected in all four samples at concentrations ranging from 0.66 mg/kg to 1.60 mg/kg. Dibenzo(a,h)anthracene was detected in all four samples at concentrations ranging from 0.13 mg/kg to 0.015 mg/kg, exceeding its ESL of 0.033 mg/kg. Indeno(1,2,3-cde)pyrene was detected in all four samples at concentrations ranging from 0.32 mg/kg to 0.55 mg/kg, exceeding its ESL of 0.15 mg/kg.

4.1.5.2 Sediment Inorganic Compounds

Eight inorganic compounds (antimony, arsenic, beryllium, chromium, copper, nickel, silver, and zinc) were detected at concentrations exceeding one or more screening level.

ESLs

Antimony was detected in two samples at concentrations ranging from 1.1 mg/kg to 1.4 mg/kg, exceeding its ESL of 0.92 mg/kg. Arsenic was detected in one sample at a concentration of 10.2 mg/kg, exceeding its ESL of 9.79 mg/kg. Beryllium was detected in one sample at a concentration of 3.1 mg/kg, exceeding its ESL of 0.8 mg/kg. Chromium was detected in two samples at concentrations ranging from 43.9 mg/kg to 50.8 mg/kg, exceeding its ESL of 43.4 mg/kg. Copper was detected in two samples at concentrations ranging from 32.0 mg/kg to 52.4 mg/kg, exceeding its ESL of 31.6 mg/kg. Nickel was detected in all four samples at concentrations ranging from 23.9 mg/kg to 36.0 mg/kg, exceeding its ESL of 22.7 mg/kg. Silver was detected in all four samples at concentrations ranging from 3.5 mg/kg to 24.8 mg/kg, exceeding its ESL of 0.5 mg/kg. Zinc was detected in all four samples at concentration ranging from 138 mg/kg to 328 mg/kg, exceeding its ESL of 121 mg/kg.

HHSLs

Arsenic was detected in all four samples at concentrations ranging from 6.6 mg/kg to 10.2 mg/kg, exceeding its HHSL of 0.39 mg/kg.

4.1.5.3 Surface Water SVOCs

Bis(2-ethylhexyl)phthalate was detected in surface water sample RD-SW-02 at a concentration of 50 µg/L, exceeding its ESL of 8.4 µg/L. This sample result of 50 µg/L also exceeds the HHSL of 6.0 µg/L, which is also the MCL.

4.1.5.4 Surface Water Inorganic Compounds

No inorganic compounds were detected in surface water samples collected from this exposure area at concentrations exceeding ESLs or HHSLs.

4.1.5.5 Exposure Area LSR-DN4 Summary

Based on the analytical results for this exposure area, the following analytes were detected in various media exceeding one or more screening level: 3,3'-dichlorobenzidine, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, phenanthrene, pyrene, antimony, arsenic, beryllium, chromium, copper, nickel, silver, and zinc.

Sediment

Analytes 3,3'-dichlorobenzidine, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3-c,d)pyrene, phenanthrene, pyrene, antimony, arsenic, beryllium, chromium, copper, nickel, silver, and zinc were detected in sediment samples at concentrations exceeding one or more screening level. Of the SVOCs that exceeded sediment screening levels, the majority exceeded ESLs. Of the inorganic compounds that exceeded sediment screening levels, the majority exceeded ESLs.

The PAHs detected throughout this exposure area vary in concentration, with no discernible source area evident. It is unlikely that the contaminants present in the sediments in this exposure area contribute significantly to the PAH contamination found in the LSR sediment because higher concentrations of PAHs are found in the LSR in other exposure areas.

Inorganic concentrations detected in this exposure area are similar to those detected in the LSR and are similar to concentrations detected in the upstream exposure area LSR-UP1.

Surface Water

Only one SVOC, bis(2-ethylhexyl)phthalate was detected in a surface water sample (RD-SW-02) collected from this exposure area. The concentration exceeded the HHSL, which is the MCL of 6.0 µg/L. No inorganic compounds were detected at concentrations exceeding screening levels in this exposure area.

Since surface water contained only one SVOC and no inorganic compounds above screening levels, it is unlikely that the surface water in this exposure area is significantly impairing downstream portions of the LSR.

4.2 BWC

ESLs and HHSLs were proposed in the original planning documents prepared for the BWC site (SulTRAC 2009). These screening levels are used in this section to be consistent with the concurrent risk assessments at the site. As a conservative measure and for completeness, soil samples are being compared with ESLs, EPA RSLs for residential soils, and EPA RSLs for industrial soils; however, the EPA RSLs for industrial soils are considered the most relevant screening level to delineate the nature and extent of contamination. Sample results for groundwater are being compared with MCLs and the EPA RSLs for tap water; however, the MCLs are considered the most relevant screening level to delineate the nature and extent of contamination.

ESLs were developed for soils at the BWC site and are consistent with EPA and Ohio EPA guidance (EPA 1998 and Ohio EPA 2003) for screening-level risk assessments. As specified in the EPA guidance, comparing soil results with ESLs is appropriate only for surface soils (0 to 2 feet bgs) given potential ecological exposure scenarios. ESLs for surface soils were based on the following sources in order of priority: EPA Ecological Soil Screening Levels (2005 through 2007), Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants (1997), Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Little Invertebrates and Heterotrophic Processes (1997), and Preliminary Remediation Goals for Ecological Endpoints (1997).

HHSLs were developed for soil and groundwater for the BWC site. Comparing soil results with HHSLs is appropriate for surface and subsurface soils. HHSLs for soil were developed using EPA Regional

Screening Levels (RSL) for residential soils and industrial soils (EPA 2012). HHSLs for groundwater were developed using EPA MCL as (EPA 2009b). If an MCL was not available, EPA RSLs for tap water (EPA 2012) were used.

Therefore, all surface soil samples were compared with the ESLs and HHSLs. All soil samples from greater than 2 feet bgs were compared with HHSLs only. All groundwater samples were compared with MCLs or RSLs for tap water when MCLs were not available.

In addition to comparing soil results with ESLs and HHSLs, background inorganic concentrations were established for soils at the BWC site. Background concentrations were obtained from Union Tank Car (PSARA 2011) and used in consultation with EPA and Ohio EPA. Background inorganic concentrations for Marion County were also obtained from USGS (USGS 2012). Where two background inorganic concentrations existed, the concentration from Union Tank Car was used based on its proximity to the BWC site. Table K-3 presents the inorganic background concentrations used for comparison. All inorganic soil samples collected at BWC were compared with applicable soil background concentrations. If a sample result exceeded a screening level but was less than the established background concentrations, the sample location is not shown in the figures describing the nature and extent of contamination.

Background concentrations were not established for VOCs and SVOCs in soils.

To establish background values for groundwater samples to be compared with, one existing shallow permanent monitoring well (MW-2S) was used and four additional shallow temporary monitoring wells (BWC-TW25, BWC-TW28, BWC-TW54, and BWC-TW55) were installed along the northern (upgradient) boundary of the BWC site and sampled for analysis of TCL VOCs, TCL SVOCs, and TAL metals. Upgradient groundwater concentrations are presented as a range in some instances where the upgradient wells exhibit variability in their concentrations. If upgradient wells exhibited the same concentration for a given chemical, that value is considered to be “background” and any concentration above it would be considered as “exceeding background.”

Each analytical result for soil and groundwater samples was first compared with the applicable screening level. If no screening level was exceeded, no additional comparison was performed on that sample result. If a screening level was exceeded and no established background concentrations were available, the sample result was used to depict the nature and extent of contamination. If a screening level was exceeded and an established background concentration was available, the sample result was then

compared with background. If the sample result did not exceed the background concentration, the sample result was not used to depict the nature and extent of contamination. If the sample result exceeded the background concentration, the sample result was used to depict the nature and extent of contamination.

SulTRAC divided BWC into two exposure areas to appropriately compare the data with project objectives:

- BWC-E – Eastern portion of the BWC property containing the former processing area
- BWC-W – Western portion of the BWC property containing the former drying area

Tables K-1 through K-10 in Appendix K present analytical results for all samples collected during the BWC investigations. Figures 39 through 47 present sample results by media that exceed one or more established screening level and an established background concentration, where available.

The nature and extent of contamination identified in these exposure areas relative to site screening levels for each type of analysis is discussed in the following subsections.

4.2.1 Extent of Contamination – Exposure Area BWC-E

A total of 100 soil samples (not including duplicate samples) were collected at multiple depths from 34 sample locations within Exposure Area BWC-E to identify the presence of contamination in the former processing area. Seventy-eight soil samples were analyzed for TCL VOCs, TCL SVOCs, and TAL metals. Sixteen soil samples were also analyzed for pesticides. Six soil samples were also analyzed for total chromium and hexavalent chromium. One surface soil sample was collected next to the slag pile in this area and analyzed for TCLP VOCs, TCLP SVOCs, TCLP RCRA metals, TCL VOCs, TCL SVOCs, and TAL metals. In addition, SulTRAC also collected one waste sample from the slag pile that was analyzed for TCLP VOCs, TCLP SVOCs, TCLP RCRA metals, TCL VOCs, TCL SVOCs, and TAL metals. SulTRAC also collected 24 groundwater samples from this area. Groundwater samples were collected to assess any impacts to groundwater and for establishing upgradient concentrations for comparison. All groundwater samples were analyzed for TCL VOCs, TCL SVOCs, and TAL metals.

Figures 39 through 43 presents all sample locations within Exposure Area BWC-E that exceeded one or more established screening level and established background concentration, where available.

4.2.1.1 Soil VOCs

No VOCs were detected at concentrations exceeding ESLs or HHSLs.

4.2.1.2 Soil SVOCs

Seventeen SVOCs (2-methylnaphthalene, acenaphthene, anthracene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, biphenyl, chrysene, dibenz[a,h]anthracene, dibenzofuran, fluoranthene, indeno[1,2,3-cd]pyrene, naphthalene, phenanthrene, and pyrene) were detected at concentrations exceeding ESLs and or HHSLs (see Figure 39). Background concentrations were not available for SVOCs in soil. Sample results compared with ESLs and HHSLs are discussed below.

Surface Soil SVOC Results

Surface soil sample SVOC results compared with ESLs and HHSLs are discussed below. One surface soil sample was collected at a depth of 0- to 2-feet bgs at each of the 34 sampling locations.

ESLs

Surface soil samples exceeded one or more of the ESLs at 18 of the 34 sample locations. Specifically, the following chemicals exceeded their ESLs in surface soils: acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, phenanthrene, and pyrene. These locations are primarily concentrated along the southern border of the site and within and directly east of the former bioremediation area. However, isolated areas of surficial SVOC contamination also exist north of the former bioremediation area near boring locations BWC-20, BWC-22, BWC-26, and BWC-30.

Residential RSLs

Surface soil samples exceeded one or more of the RSLs for residential soils at 28 of the 34 surface soil sample locations. Specifically, the following chemicals in surface soil samples exceeded the EPA RSLs for residential soil: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, dibenzofuran, indeno(1,2,3-cd)pyrene, and naphthalene. The surface soil sampling locations that exceed one or more residential soil RSLs are generally located throughout the exposure area but primarily along the southern boundary of the exposure area and within and directly east of the former bioremediation area. However, isolated areas of SVOC contamination also exist north of the

former bioremediation area near boring locations BWC-20, BWC-22, BWC-25, BWC-26, BWC-28, and BWC-30.

Industrial RSLs

Surface soil samples exceeded one or more of the RSLs for industrial soils at 24 of the 34 surface soil sample locations. Specifically, the following chemicals in surface soil samples exceeded the EPA RSL for industrial soil: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and naphthalene. The surface soil sampling locations that exceed one or more RSLs for industrial soil are located throughout the exposure area but are primarily located along the southern boundary of the exposure area and within and directly east of the former bioremediation area. However, isolated areas of SVOC contamination exist north of the former bioremediation area at sample locations BWC-20, BWC-22, BWC-25, BWC-26, and BWC-30.

Subsurface Soil SVOC Results

Subsurface soil sample results for SVOCs are compared with HHSLs below. A total of 44 subsurface soil samples were collected from various depths at 34 sample locations.

Residential RSLs

Subsurface soil samples exceeded one or more of the RSLs for residential soil at 10 of the 34 soil sample locations. Specifically, the following chemicals in subsurface soil samples exceeded one or more EPA RSL for residential soil: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, biphenyl, chrysene, dibenz(a,h)anthracene, dibenzofuran, indeno(1,2,3-cd)pyrene, and naphthalene. The subsurface soil sampling locations that exceed one or more RSL for residential soil are primarily located along the southern boundary of the exposure area and within and directly east of the former bioremediation area. However, isolated areas of SVOC contamination exist north of the former bioremediation area at sample locations BWC-26 and BWC-30.

Industrial RSLs

Subsurface soil samples exceeded one or more of the RSLs for industrial soil at nine of the 34 soil sample locations. Specifically, the following chemicals in subsurface soil samples exceeded the EPA RSL for industrial soil: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene, and naphthalene. The subsurface soil sampling locations that exceed one or more RSLs for industrial soil are primarily located within and directly east of the former bioremediation area as well as at sampling location BWC-30.

4.2.1.3 Soil Inorganic Compounds

Fifteen inorganic compounds (arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc) were detected at concentrations exceeding the ESLs, HHSLs, and established background concentrations (see Figure 40). Sample results for surface and subsurface soil are compared with ESLs and HHSLs below.

Surface Soil Inorganic Compounds Results

Surface soil sample results for inorganic compounds are compared with ESLs and HHSLs below. One surface soil sample was collected at a depth of 0- to 2-feet bgs at each of the 34 sampling locations.

ESLs

Surface soil samples exceeded one or more of the ESLs and background when available at all 34 of the 34 sample locations. Specifically, the following chemicals in surface soil samples exceeded their ESLs : arsenic, barium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium, thallium, vanadium, and zinc. Taking into consideration available background information, the following chemicals were eliminated from consideration because surface soil sample results did not exceed background: cadmium, copper, mercury, and selenium. Vanadium results exceeded the ESL of 2 mg/kg in all 34 sample locations; vanadium does not have a background concentration. Arsenic results exceeded the ESL of 18 mg/kg and the background concentration of 15.8 mg/kg in nine samples from nine sample locations . The nine sample locations where arsenic was detected above the background concentration and ESL are primarily located within and directly east of the former bioremediation area, along the eastern boundary of the exposure area, and directly north of the former bioremediation area. Chromium results exceeded the ESL of 0.4 mg/kg and the background concentration of 20.8 mg/kg in 19 samples from 19 locations. The 19 sample locations where chromium was detected above background concentrations and the ESL are primarily located within and directly east of the former bioremediation area, along the southern and eastern boundary of the exposure area and directly north of the former bioremediation area. Lead results exceeded the ESL of 11 mg/kg and the background concentration of 17.1 mg/kg in 19 samples from 19 locations. Barium results exceeded the ESL of 330 mg/kg and the background concentration of 164 mg/kg in three samples from BWC-05B, BWC-06D, and BWC-22. Manganese results exceeded the ESL of 220 mg/kg and the background concentration of 491.391 mg/kg in four samples from BWC-06D, BWC-06E, BWC-18, and BWC-22. Thallium results exceeded the ESL of 1 mg/kg in one sample from one sample location ; thallium does not have a background concentration. Cobalt results exceeded the ESL of 13 mg/kg in three samples from three sample locations; cobalt does

not have a background concentration. Nickel results exceeded the ESL of 38 mg/kg in two samples from two sample locations; nickel does not have a background concentration.

Residential RSLs

Surface soil samples exceeded one or more of the RSLs for residential soil at all 34 sample locations. Specifically, the following chemicals in surface soil samples exceeded the EPA RSL for residential soil: arsenic, cobalt, iron, lead, manganese, and thallium. Arsenic results exceeded the RSL of 0.39 mg/kg and the background concentration of 15.8 mg/kg in nine surface soil samples from nine sample locations. The nine sample locations where arsenic was detected above the background concentration and RSL for residential soil are primarily located within and directly east of the former bioremediation area, along the eastern boundary of the exposure area, and directly north of the former bioremediation area. Lead results exceeded the RSL of 400 mg/kg and the background concentration of 17.1 mg/kg in one sample from BWC-22. Manganese results exceeded the RSL of 1,800 mg/kg and the background concentration of 491.391 mg/kg in four samples from BWC-06D, BWC-18, and BWC-22. Iron results exceeded the RSL of 55,000 mg/kg in two samples from BWC-06D and BWC-22; iron has no background concentration. Thallium results exceeded the RSL of 0.78 mg/kg in one surface soil sample (BWC-16); thallium has no background concentration. Cobalt results exceeded the RSL of 23 mg/kg in one sample from BWC-22; cobalt has no background concentration.

Industrial RSLs

Surface soil samples exceeded one or more of the RSLs for industrial soil at all 34 sample locations. Specifically, the following chemicals in surface soil samples exceeded the EPA RSL for industrial soil: arsenic and lead. Arsenic results exceeded the RSL of 1.6 mg/kg and background concentration of 15.8 mg/kg in nine surface soil samples from nine sample locations. The nine sample locations where arsenic was detected above the background concentration and RSL for industrial soil are primarily located within and directly east of the former bioremediation area, along the eastern boundary of the exposure area, and directly north of the former bioremediation area. Lead results exceeded the RSL of 800 mg/kg and the background concentration of 17.1 mg/kg in one sample from sample location BWC-22.

Subsurface Soil Inorganic Compounds Results

Subsurface soil results for inorganic compounds results are compared with HHSLs. A total of 44 subsurface soil samples from various depths were collected from 34 sample locations.

Residential RSLs

Subsurface soil samples exceeded one or more of the RSLs for residential soils at all 44 sampling locations collected from 34 sample locations. Specifically, the following chemicals exceeded the EPA RSL for residential soils: arsenic and thallium. Arsenic results exceeded the RSL of 0.39 mg/kg and the background concentration of 15.8 mg/kg in six subsurface soil samples from BWC-01, BWC-05, BWC-06G, BWC-14, BWC-21, and BWC-27. Thallium results exceeded the RSL of 0.78 mg/kg in eight subsurface soil samples in locations (BWC-04, BWC-05, BWC-06, BWC-07, BWC-13, BWC-14, and BWC-30) along the eastern boundary and within or directly east of the former bioremediation area; thallium has no background concentration.

Industrial RSLs

Arsenic was the only contaminant that exceeded its RSL for industrial soil. Arsenic results exceeded the RSL of 1.6 mg/kg for industrial soil and the background concentration of 15.9 mg/kg in six samples from BWC-01, BWC-05, BWC-06G, BWC-14, BWC-21, and BWC-27.

4.2.1.4 Soil Pesticides

Four pesticides (4,4'-DDT, chlordane, dieldrin, and toxaphene) were detected at concentrations exceeding the ESL and or HHSLs in six samples collected from five sample locations within the exposure area.

ESLs

4,4'-DDT was detected in one soil sample collected at BWC-06H from 1- to 3-feet bgs at a concentration of 5.6 micrograms per kilogram ($\mu\text{g/kg}$), exceeding its ESL of 3.5 $\mu\text{g/kg}$. Chlordane was detected in one soil sample collected at BWC-07 from a depth of 0- to 2-feet bgs at a concentration of 583.8 $\mu\text{g/kg}$, exceeding its ESL of 224 $\mu\text{g/kg}$. Dieldrin was detected in one soil sample collected at BWC-04 from a depth of 0- to 2-feet bgs at a concentration of 3.7 $\mu\text{g/kg}$, exceeding its ESL of 2.38 $\mu\text{g/kg}$. Toxaphene was detected in six soil samples at various depths at concentrations ranging from 125 $\mu\text{g/kg}$ to 1,880 $\mu\text{g/kg}$, exceeding its ESL of 119 $\mu\text{g/kg}$.

HHSLs

Toxaphene was detected in two soil samples exceeding one or more of its HHSLs. The concentration at sample location BWC-04 was 1,880 $\mu\text{g/kg}$, exceeding both the RSL for residential soil (440 $\mu\text{g/kg}$) and the RSL for industrial soil (1,600 $\mu\text{g/kg}$). The concentration at sample location BWC-07 was 451 $\mu\text{g/kg}$, exceeding only its RSL for residential soil (440 $\mu\text{g/kg}$). Both samples were collected from 0 to 2 feet bgs.

4.2.1.5 Waste (Slag Pile) and Surrounding Surface Soils

The slag pile was sampled for TCL VOCs, TCL SVOCs, TAL metals, TCLP VOCs, TCLP SVOCs, and TCLP metals. The slag pile was a composite sample made up of material collected and homogenized from five areas of the pile. No VOCs were detected at concentrations exceeding the ESLs or HHSLs. Four SVOCs (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, and indeno[1,2,3-cd]pyrene) were detected at concentrations exceeding the ESLs and or HHSLs in the slag pile. Benzo(a)anthracene exceeded both the ESL of 1,100 µg/kg and the RSL for residential soil of 150 µg/kg. Benzo(a)pyrene exceeded both the ESL of 1,100 µg/kg and the RSLs for residential soil (15 µg/kg) and industrial soil (210 µg/kg). Benzo(b)fluoranthene exceeded both the ESL of 1,100 µg/kg and the RSL for residential soil of 150 µg/kg. Indeno(1,2,3-cd)pyrene exceeded both the ESL of 1,100 µg/kg and the RSL for residential soil of 150 µg/kg. Eight inorganic compounds (arsenic, chromium, cobalt, copper, iron, manganese, nickel, and vanadium) were detected at concentrations exceeding the ESLs and or HHSLs. The concentration of arsenic (51.8 mg/kg) exceeded its ESL of 18 mg/kg, the RSL for residential soil of 0.39 mg/kg, and the RSL for industrial soil of 1.6 mg/kg. Arsenic also exceeded its established background concentration of 15.8 mg/kg. The concentration of chromium (2,060 mg/kg) exceeded only its ESL of 0.4 mg/kg and its established background concentration of 20.8 mg/kg. The concentration of cobalt (72.6 mg/kg) exceeded both its ESL of 13 mg/kg and its RSL for residential soil of 23 mg/kg. No background value for cobalt has been established. The concentration of copper (1,130 mg/kg) exceeded its ESL of 28 mg/kg as well as its established background of 29.611 mg/kg. The concentration of iron (634,000 mg/kg) exceeded its RSL for residential soil of 55,000 mg/kg. No background value for iron has been established. The concentration of manganese (5,670 mg/kg) exceeded its ESL of 220 mg/kg, the RSL for residential soil of 1,800 mg/kg, and its established background of 491.391 mg/kg. The concentration of nickel (2,040 mg/kg) exceeded its ESL of 38 mg/kg and the RSL for residential soil of 1,500 mg/kg. No background value for nickel has been established. The concentration of vanadium (49.0 mg/kg) exceeded its ESL of 2 mg/kg. No background value for vanadium has been established.

A surface soil sample collected from soil directly adjacent to the slag pile was analyzed for TCL VOCs, TCL SVOCs, TAL metals, TCLP VOCs, TCLP SVOCs, and TCLP metals. The surface soil was a composite sample made up of surface soils collected and homogenized from five areas directly adjacent to the slag pile. No VOCs were detected at concentrations exceeding the ESLs or HHSLs. Eight SVOCs (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, indeno[1,2,3-cd]pyrene, and pyrene) were detected at concentrations exceeding the ESLs and or HHSLs in the surface soil sample. Benzo(a)anthracene was detected at a concentration (7,360 µg/kg) exceeding its ESL of 1,100 µg/kg and its RSL for residential soil (150 µg/kg) and industrial soil (2,100

µg/kg). Benzo(a)pyrene was detected at a concentration (6,810 µg/kg) exceeding its ESL of 1,100 µg/kg and its RSL for residential soil (15 µg/kg) and industrial soil (210 µg/kg). Benzo(b)fluoranthene was detected at a concentration (7,930 µg/kg) exceeding its ESL of 1,100 µg/kg and its RSL for residential soil (150 µg/kg) and industrial soil (2,100 µg/kg). Benzo(g,h,i)perylene was detected at a concentration (4,450 µg/kg) exceeding its ESL of 1,100 µg/kg. Benzo(k)fluoranthene was detected at a concentration (8,430 µg/kg) exceeding its ESL of 1,100 µg/kg and RSL for residential soil of 1,500 µg/kg. Chrysene was detected at a concentration (9,560 µg/kg) exceeding its ESL of 1,100 µg/kg. Indeno(1,2,3-cd)pyrene was detected at a concentration (4,750 µg/kg) exceeding its ESL of 1,100 µg/kg and its RSL for residential soil (150 µg/kg) and industrial soil (2,100 µg/kg). Pyrene was detected at a concentration (15,600 µg/kg) exceeding its ESL of 1,100 µg/kg. Ten inorganic compounds (arsenic, chromium, cobalt, copper, iron, lead, manganese, nickel, vanadium, and zinc) were detected at concentrations exceeding one or more ESLs and or HHSLs. Arsenic was detected at a concentration (33 mg/kg) exceeding its ESL of 18 mg/kg, the RSL for residential soil of 0.39 mg/kg, and the RSL for industrial soil of 1.6 mg/kg. Arsenic also exceeded its established background concentration of 15.8 mg/kg. Chromium was detected at a concentration (1,090 mg/kg) exceeding its ESL of 0.4 mg/kg and its established background of 20.8 mg/kg. Cobalt was detected at a concentration (39.3 mg/kg) exceeding its ESL of 13 mg/kg and RSL for residential soil of 23 mg/kg. No background value has been established for cobalt. Copper was detected at a concentration (600.0 mg/kg) exceeding its ESL of 28 mg/kg and its established background of 29.611 mg/kg. Iron was detected at a concentration (312,000 mg/kg) exceeding its RSL for residential soil of 55,000 mg/kg. No background value has been established for iron. Lead was detected at a concentration (46.2 mg/kg) exceeding its ESL of 11 mg/kg and its background of 17.1 mg/kg. Manganese was detected at a concentration (3,880 mg/kg) exceeding its ESL of 220 mg/kg and the RSL for residential soil of 1,800 mg/kg. The concentration of manganese also exceeded its established background of 491.391 mg/kg. Nickel was detected at a concentration (1,050 mg/kg) exceeding its ESL of 38 mg/kg. No background value has been established for nickel. Vanadium was detected at a concentration (44.1 mg/kg) exceeding its ESL of 2 mg/kg. No background value has been established for vanadium. Zinc was detected at a concentration (91.9 mg/kg) exceeding its ESL of 46 mg/kg but not its established background of 113.005 mg/kg.

No TCLP VOCs, TCLP SVOCs, or TCLP metals were detected above the TCLP regulatory levels in either the slag pile or the surface soil sample.

4.2.1.6 Groundwater VOCs

Two VOCs (benzene and ethylbenzene) were detected at concentrations exceeding the HHSLs in nine groundwater wells sampled in this exposure area (see Figure 41).

Benzene was detected at concentrations exceeding its RSL for tap water (0.39 µg/L) in nine groundwater samples collected from seven temporary monitoring wells and two permanent shallow monitoring wells. Concentrations of benzene in these nine wells ranged from 0.42 µg/L to 41.7 µg/L. Benzene was detected at concentrations exceeding its MCL (5.0 µg/L) in two groundwater samples collected from two temporary monitoring wells. Concentrations of benzene in these two wells ranged from 9.8 µg/L to 41.7 µg/L in wells GW-06A and GW-06. The upgradient concentration of benzene was established at 1 µg/L. This concentration was detected in the upgradient wells and is used for comparison. Using this upgradient concentration, six of the nine groundwater samples continue to exceed the RSL for tap water and the established upgradient concentration, and both groundwater samples that exceeded the MCL still exceed the established upgradient concentration. All benzene concentrations exceeding the RSL for tap water, MCL, and upgradient concentration are located within the former bioremediation area.

Ethylbenzene was detected at concentrations exceeding its RSL for tap water (1.3 µg/L) in three groundwater samples collected from three temporary monitoring wells. Concentrations of ethylbenzene in these three wells ranged from 7.2 µg/L to 51.5 µg/L. Ethylbenzene was not detected at concentrations exceeding its MCL of 700 µg/L. The upgradient concentration of ethylbenzene was established at 1 µg/L. Using this upgradient concentration, all three groundwater samples continue to exceed upgradient concentrations and the RSL for tap water. All three well locations (BWC-06, BWC-06A, and BWC-06H) are located within the southern part of the former bioremediation area.

4.2.1.7 Groundwater SVOCs

Eight SVOCs (acenaphthene, benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, biphenyl, dibenzofuran, N-nitrosodiphenylamine, and naphthalene) were detected at concentrations exceeding the HHSLs in 13 groundwater wells (11 temporary monitoring wells and two permanent monitoring wells) sampled in this exposure area (see Figure 42). Acenaphthene was detected at a concentration of 419 µg/L at one temporary monitoring well (BWC-GW53) exceeding its RSL for tap water (400 µg/L) and its upgradient concentration range of 5.2 µg/L to 5.6 µg/L. Benzo(a)anthracene was detected at concentrations ranging from 0.67 µg/L to 2.4 µg/L in three temporary monitoring wells (BWC-GW06A, BWC-GW06I, and BWC-GW53), exceeding the RSL for tap water (0.029 µg/L) but not the upgradient

concentration range of 5.2 µg/L to 5.6 µg/L. Benzo(a)pyrene was detected at a concentration of 0.93 µg/L at one temporary monitoring well (BWC-GW53) exceeding its RSL for tap water (0.0029 µg/L) and its MCL (0.2 µg/L); however, benzo(a)pyrene did not exceed its upgradient concentration range of 5.2 µg/L to 5.6 µg/L. Benzo(b)fluoranthene was detected at a concentration of 1.0 µg/L at one temporary monitoring well (BWC-GW53), exceeding its RSL for tap water (0.029 µg/L) but not its upgradient concentration range of 5.2 µg/L to 5.6 µg/L. Biphenyl was detected at concentrations ranging from 6.1 µg/L to 78.8 µg/L at three temporary monitoring wells (BWC-GW06, BWC-GW06A, and BWC-GW06H), exceeding its RSL for tap water (0.83 µg/L) and its upgradient concentration range of 10.3 µg/L to 11.2 µg/L in two (BWC-GW06 and BWC-GW06H) of the three temporary monitoring wells. Dibenzofuran was detected at concentrations ranging from 5.9 µg/L to 290 µg/L in 11 temporary monitoring wells and one permanent shallow monitoring well, exceeding its RSL for tap water (5.8 µg/L) and the upgradient concentration range of 5.2 µg/L to 5.6 µg/L. N-Nitrosodiphenylamine was detected at a concentration of 16.4 µg/L in one temporary monitoring well (BWC-GW06I), exceeding its RSL for tap water (10 µg/L) and its upgradient concentration range of 10.3 µg/L to 11.2 µg/L. Naphthalene was detected at concentrations ranging from 0.87 µg/L to 3,400 µg/L in eight temporary monitoring wells and two permanent shallow monitoring wells, exceeding its RSL for tap water (0.14 µg/L). However, only five of the temporary monitoring well locations (BWC-GW05, BWC-GW06, BWC-GW06A, BWC-GW06H, and BWC-GW53) also exceeded the upgradient concentration range of 5.2 µg/L to 5.6 µg/L. All temporary monitoring wells that exceeded either its RSL for tap water, MCL, and also upgradient concentration range are all located within or directly east of the former bioremediation area.

4.2.1.8 Groundwater Inorganic Compounds

Fifteen inorganic compounds (aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, vanadium, and zinc) were detected at concentrations exceeding the HHSLs in 15 groundwater wells sampled in this exposure area (see Figure 43). Temporary monitoring well BWC-GW22 was the only groundwater sampling location that had concentrations of the following inorganic compounds detected at concentrations exceeding the MCL and or RSL for tap water: aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, mercury, nickel, vanadium, and zinc. In the temporary monitoring well, the MCL was exceeded for barium, beryllium, cadmium, chromium, copper, lead, and mercury. The RSL for tap water was exceeded for aluminum, cadmium, cobalt, copper, iron, mercury, nickel, vanadium, and zinc.

Arsenic was detected at concentrations ranging from 0.6 µg/L to 229 µg/L in 15 groundwater wells (10 temporary monitoring wells, three permanent deep monitoring wells, and two permanent shallow

monitoring wells) exceeding its RSL for tap water (0.045 µg/L). Arsenic was detected at a concentration (229 µg/L) exceeding its MCL (10 µg/L) at one temporary monitoring well location (BWC-GW22). The upgradient concentration range for arsenic was 9.4 µg/L to 20 µg/L. Using that upgradient concentration range, only sample at location BWC-GW22 still exceeds the RSL for tap water and the MCL.

Manganese was detected at concentrations ranging from 465 µg/L to 7,510 µg/L in three temporary monitoring well locations exceeding its RSL for tap water (320 µg/L). The upgradient concentration range was established from 5.8 µg/L to 163 µg/L; therefore, all three well locations (BWC-GW06, BWC-GW22, and BWC-GW53) continue to exceed the RSL for tap water.

Besides temporary monitoring well BWC-GW22, temporary monitoring wells and permanent monitoring wells that exceed the RSL for tap water and or MCL as well as the upgradient concentration range are primarily located within or directly east of the former bioremediation area. Well BWC-GW22 is located north of the former bioremediation area.

4.2.1.9 Product

As discussed in Section 2.0, soil borings were drilled and field screened using LIF technology to assess the potential presence of product (either light nonaqueous-phase liquid [LNAPL] or dense nonaqueous-liquid [DNAPL]). Based on LIF screening results, DNAPL was suspected in the following boring locations; BWC-05, BWC-06, BWC-06A, BWC-06B, BWC-06C, BWC-06D, BWC-06E, BWC-06F, BWC-06H, BWC-06I, and BWC-07. Based on the wavelength frequencies obtained, a mixture of creosote and fuel (such as gasoline or diesel fuel) was detected in the majority of those locations; however, based on the readings, it is believed that locations BWC-06 and BWC-06A contained mostly creosote while the other locations contained either a similar amount of each or mostly fuel. LIF screening results are presented in Appendix D.

Based on LIF results, soil borings were drilled and soil samples were collected to obtain analytical results for surface and subsurface soil. During advancement of soil borings, product, staining, sheens, and odors were observed at several locations and various depths. Table 4-1 summarizes field observations during soil boring and sampling activities.

Table 4-1
Field Observations During Soil Boring and Sampling Activities – BWC-E

Boring Number	Depth (ft bgs)	Odor	Sheen	Staining	Product	Comments
BWC-03A	12 - 13	X				Fuel
BWC-05	9 - 11		X	X	X	Creosote
BWC-05B	14.5 - 15	X	X			Creosote/Fuel
BWC-06	4 - 18	X	X	X	X	Creosote
BWC-06A	15 - 16	X	X			Creosote
BWC-06B	16 - 17	X				Creosote
BWC-06C	13 - 17	X	X			Creosote/Fuel
BWC-06E	4 - 17.5	X				Creosote
BWC-06F	13.5 - 18	X				Fuel
BWC-06G	12 - 13	X				Fuel
BWC-06H	12 - 15			X		Creosote
BWC-06I	12 - 17.5	X				Fuel
BWC-07	0 - 17	X				Fuel
BWC-13	16 - 17	X		X		Creosote/Fuel
BWC-14	16 - 17	X	X			Fuel
BWC-52	7 - 18.5	X	X		X	Creosote/Fuel
BWC-53	4 - 11	X			X	Creosote

Odors were observed at 15 soil boring locations within the exposure area. Sheen or staining were observed in nine soil boring locations and product was observed in four boring locations. Five locations (BWC-06, BWC-06E, BWC-07, BWC-52, and BWC-53) presented with odors, sheen, staining or product observed throughout most of the boring. The remaining 10 locations presented with observations of odors, sheens, staining, or product at or just above the bedrock interface.

During the August 2011, November 2011, and February 2012 investigations, an interface probe was used to collect water level measurements from existing temporary and permanent monitoring wells as well as to determine if product was present in any of the wells. Figures 48 through 56 presents those wells with observed products, sheens, or odors in at least one of the water level measurement events. Table 4-2 summarizes field measurements and observations.

Table 4-2
Observed Product, Sheens, or Odors During Water Level Measurement Events – BWC-E

Well ID	August 2011	November 2011	February 2012
Field Measurements and Observations			
BWC-GW03A	Fuel odor	--	Fuel odor and 0.01 foot product
BWC-GW05	Strong creosote and fuel odor and 0.05 foot of product	Creosote odor and sheen	Creosote odor
BWC-GW05B	Strong fuel odor and 0.06 foot of product	Strong fuel odor	Fuel odor and 0.10 foot of product
BWC-GW06	Strong creosote odor	Creosote and fuel odors and presence of a sheen	Creosote and fuel odors and presence of a sheen
BWC-GW06A	Strong creosote odor	Creosote and fuel odors and presence of a sheen	Creosote and fuel odors and presence of a sheen
BWC-GW06C	Strong creosote and fuel odor	Fuel odor and sheen	Fuel odor
BWC-GW06F	Strong creosote and fuel odor and 0.02 foot of product	Creosote and fuel odors and presence of a sheen	Creosote and fuel odors and presence of a sheen
BWC-GW06H	Strong creosote odor	Creosote and fuel odors and presence of a sheen	Creosote and fuel odors and presence of a sheen
BWC-GW06I	Strong fuel odor and 0.05 foot of product	Creosote and fuel odors and presence of a sheen	Creosote and fuel odors and presence of a sheen
BWC-GW13	Strong fuel odor and 0.02 foot of product	Slight fuel odor	Fuel odor and 0.04 foot of product
BWC-GW15	Slight fuel odors	--	Fuel odor
BWC-GW22	Slight fuel odors	--	--
BWC-GW53	NA	Creosote and fuel odors and presence of a sheen	Creosote and fuel odors and presence of a sheen

During the August 2011 investigation, odors were detected at 12 temporary monitoring wells and a sheen or product was observed at five temporary monitoring wells. Specifically, product was observed at temporary monitoring wells BWC-GW05, BWC-GW05B, BWC-GW06F, BWC-GW06I, and BWC-GW13. Three of the five temporary monitoring wells with product are located within the former bioremediation area. The remaining two are located just east and southeast of the former bioremediation area.

During the November 2011 investigation, odors were detected in 10 temporary monitoring wells and a sheen was observed at eight temporary monitoring well locations. No measurable product was detected in any of the temporary monitoring wells in November 2011.

During the February 2012 investigation, odors were detected at 12 temporary monitoring wells and a sheen or product was observed at nine temporary well locations. Specifically, product was observed at temporary monitoring wells BWC-GW03A, BWC-GW05B, and BWC-GW13. Two of the three temporary monitoring wells with product are located within the former bioremediation area. Temporary monitoring well BWC-GW03A is located in the southeast portion of the exposure area near the southern boundary.

4.2.1.10 Exposure Area BWC-E Summary

Based on the analytical results for this exposure area, the following analytes were detected in various media exceeding one or more screening levels: 2-methylnaphthalene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, biphenyl, chrysene, dibenz(a,h)anthracene, dibenzofuran, fluoranthene, ideno(1,2,3-cd)pyrene, N-nitrosodiphenylamine, naphthalene, phenanthrene, pyrene, benzene, ethylbenzene, aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, thallium, vanadium, zinc, 4,4'-DDT, chlordane, dieldrin, and toxaphene. Soil, waste, and groundwater sampling results are summarized below.

Soil

No VOCs were detected at concentrations exceeding the ESLs or HHSLs. Analytes 2-methylnaphthalene, acenaphthene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, biphenyl, chrysene, dibenz(a,h)anthracene, dibenzofuran, fluoranthene, ideno(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene, arsenic, barium, chromium, cobalt, copper, iron, lead, manganese, nickel, selenium, thallium, vanadium, zinc, 4,4'-DDT, chlordane, dieldrin, and toxaphene were detected in soil samples at concentrations exceeding one or more screening levels and background concentrations, where available. In general, the majority of SVOCs detected above screening levels in soil samples exceeded the ESL in surface soils. All soil sample locations contained one or more inorganic compounds exceeding both ESLs and HHSLs.

SVOC soil contamination is greatest near the former bioremediation area and extends east to the property boundary, south toward Holland Road, and west to the boundary of BWC-E. To the north, SVOC contamination exists at sample locations BWC-20, BWC-22, BWC-25, BWC-26, BWC-28, and BWC-30 but does not include the area encompassing BWC-21 and BWC-27 or the area near monitoring well MW2. The majority of surface soil samples exceeded both the ESL and residential and industrial RSLs for SVOCs throughout the entire exposure area, with the highest concentrations being within and directly east of the former bioremediation area as well as sample location BWC-30. Similar to the surface soil samples, those samples collected at a depth greater than 2-feet bgs exceeded the residential and industrial RSLs and were located within and directly east of the former bioremediation area as well as sample locations BWC-26 and BWC-30.

Arsenic is present throughout exposure area BWC-E at concentrations exceeding the ESL and residential and industrial HHSLs for both surface and subsurface soils (18 mg/kg, 0.39 mg/kg and 1.6 mg/kg). Arsenic concentrations ranged from 3.5 mg/kg to 43.3 mg/kg with the highest concentration located directly east of the former bioremediation area at sample location BWC-05B. Arsenic exceeded the ESL (18 mg/kg) in eight surface soil samples and exceeded the residential and industrial RSLs (0.39 mg/kg and 1.6 mg/kg) in all soil samples (surface and subsurface) throughout the entire exposure area. However, when background is taken into consideration, arsenic exceeds a screening level at only 17 sample locations, primarily located within, directly east, and directly north of the former bioremediation area.

Chromium is also present throughout exposure area BWC-E in both surface soil and subsurface soil samples; however, chromium exceeds its ESL (0.4 mg/kg) only at the 34 surface soil sample locations and does not ever exceed its HHSLs. When background is taken into consideration, chromium then exceeds its ESL at only 19 sample locations, with the highest concentrations in the former bioremediation area, the eastern boundary and at location BWC-22.

Thallium is present in soil samples mainly along the southern and eastern boundaries of exposure area BWC-E but was also detected in samples within and just east of the former bioremediation area. Thallium was detected at concentrations ranging from 0.81 mg/kg to 5.8 mg/kg, which exceed only the residential HHSL of 0.78 mg/kg.

Vanadium also is present in all surface soil samples collected from the exposure area at concentrations exceeding its ESL of 2 mg/kg. Vanadium was detected at concentrations ranging from 8.9 mg/kg to 106

mg/kg, with the highest concentration occurring at sample location BWC-06D, located within the former bioremediation area.

Other inorganic compounds detected at concentrations above one or more screening levels are mostly concentrated at location BWC-22, located northwest of the former bioremediation area. The source of the elevated inorganic compounds concentrations is not known, but the impacts appear to be localized since the elevated results do not occur at other sampling locations in the exposure area.

The pesticides 4,4'-DDT, chlordane, dieldrin, and toxaphene were detected at five sample locations within the exposure area at concentrations exceeding the ESLs. Toxaphene was also detected at two sample locations (BWC-04 and BWC-07) exceeding its residential RSL and was detected at one sample location BWC-04 exceeding its industrial RSL. With the exception of one sample collected from 5 to 7 feet bgs (at sample location BWC-06I), the five other samples were collected from the 0- to 2-feet interval (BWC-04, BWC-07, and BWC-14) or the 1- to 3-feet interval (BWC-06H and BWC-06I).

Concentrations of pesticides exceeding screening levels are observed along the southern border of the former bioremediation area, one area just west of the former bioremediation area, and two locations east of the former bioremediation area.

Waste (Slag Pile) and Surrounding Surface Soil

One waste sample was collected from the slag pile located northeast of the former bioremediation area. Analytes benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, ideno(1,2,3-cd)pyrene, arsenic, chromium, cobalt, copper, iron, manganese, nickel, and vanadium were detected in the waste sample at concentrations exceeding one or more screening levels and background concentrations where available. In general, the waste sample for both SVOC and inorganic compounds contamination exceeded the ESL the majority of the time. With the exception of arsenic and benzo(a)pyrene, no other analytes exceeded the RSL for industrial soils.

SVOC concentrations in the slag pile exceeded only the residential HHSLs with the exception of benzo(a)pyrene, which also exceeded its industrial HHSL. Inorganic compounds concentrations in the slag pile usually exceeded only the ESL or residential HHSL with the exception of arsenic, which also exceeded its industrial HHSL.

One surface soil sample was collected from soil immediately adjacent to the slag pile. Analytes benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene,

chrysene, ideno(1,2,3-cd)pyrene, pyrene, arsenic, chromium, cobalt, copper, iron, lead, manganese, nickel, vanadium, and zinc were detected in the surface soil sample at concentrations exceeding one or more screening levels and background concentrations where available. In general, the surface soil sample exceeded the ESL for inorganic compounds and both the ESLs and HHSLs for SVOCs.

TCLP parameters were not detected at concentrations above regulatory concentrations that would suggest that the material in the slag pile or surrounding soils is able to leach to the deeper soils or groundwater. TCLP results also indicate that the slag pile and surrounding soil would most likely be considered nonhazardous for disposal purposes.

Groundwater

Analytes benzene, ethylbenzene, acenaphthene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, biphenyl, dibenzofuran, N-nitrosodiphenylamine, naphthalene, aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, vanadium, and zinc were detected in groundwater samples at concentrations exceeding one or more screening levels and background concentrations, where available. In general, the majority elevated results in groundwater samples with regards to SVOC and inorganic compounds contamination exceeded the RSL for tap water, with relatively fewer results that exceeded MCLs.

Benzene exceeded its RSL for tap water in nine groundwater samples but exceeded its MCL only at two groundwater sample locations. Both locations where the MCL was exceeded are located at locations BWC-06 and BWC-06A, within the former bioremediation area. Ethylbenzene exceeded its RSL for tap water in three groundwater samples and did not exceed its MCL. All three well locations (BWC-GW06, BWC-GW06A, and BWC-GW06H) are located within the former bioremediation area, which is the same locations where benzene is above its MCL.

Benzo(a)pyrene was the only SVOC that exceeded its MCL, at location BWC-GW53, which is located directly east of the former bioremediation area. The remaining SVOCs were detected at concentrations exceeding the RSLs for tap water at 12 groundwater wells. The majority of SVOCs exceeding the RSL for tap water occurred in locations BWC-GW06, BWC-GW06A, BWC-GW06H, and BWC-GW53; however, BWC-GW06I contained a concentration of N-nitrosodiphenylamine exceeding its RSL for tap water. Therefore, the majority of SVOC contamination is found in temporary monitoring wells located within and directly east of the former bioremediation area.

Arsenic is present in the groundwater throughout BWC-E at concentrations exceeding the RSLs for tap water (0.045 µg/L); however, arsenic exceeded its MCL (10 µg/L) only at one sample location, BWC-GW22. When the upgradient concentration range for arsenic is considered, BWC-GW22 is the only location where arsenic still exceeds its RSL and MCL. Manganese is present in groundwater at three locations (BWC-GW06, BWC-GW22, and BWC-GW53) within the exposure area exceeding its RSL and upgradient concentration range. The other inorganic compounds detected in groundwater at concentrations above an RSL or upgradient concentration range were detected at BWC-GW22. The source of the elevated inorganic compounds concentrations is not known but the impacts appear to be localized, since the majority of inorganic compounds detected in groundwater at this location (aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, vanadium, and zinc) are not detected at concentrations exceeding HHSLs in the remainder of the exposure area. Therefore, with the exception of BWC-GW22, metal contamination in groundwater is located within and directly east of the former bioremediation area.

Based on field observations, product has been observed in numerous temporary monitoring wells in this exposure area, most concentrated within and directly east of the former bioremediation area. Three investigations occurred and similar results were observed in all three events, with the majority of creosote product or odors observed within the former bioremediation area and directly east (wells BWC-GW05 and BWC-GW53), while fuel odors and sheens are observed along the southern border of the exposure area.

Based on LIF screening results, DNAPL was detected in the following boring locations; BWC-05, BWC-06, BWC-06A, BWC-06B, BWC-06C, BWC-06D, BWC-06E, BWC-06F, BWC-06H, BWC-06I, and BWC-07. Based on analytical results and observations, the LIF screening results are supported and tended to detect the presence of creosote, fuel, or both at these locations. As with field observations and analytical results for groundwater and soil, these locations were located within the former bioremediation area, or just directly east (BWC-05) and west (BWC-07).

4.2.2 Extent of Contamination – Exposure Area BWC-W

A total of 55 soil samples, not including duplicates, were collected from 25 sample locations within Exposure Area BWC-W to identify the presence of contamination in the former drying area. All 55 soil samples were analyzed for TCL VOCs, TCL SVOCs, and TAL metals. SulTRAC also collected two additional soil samples that were analyzed for total and hexavalent chromium. SulTRAC also collected

eight groundwater samples, not including duplicates, from this area. Groundwater samples were collected to assess potential impacts to groundwater. All groundwater samples were analyzed for TCL VOCs, TCL SVOCs, and TAL metals.

Figures 44 through 47 presents all sample locations within Exposure Area BWC-W that exceeded one or more established screening levels and established background concentrations, where available.

4.2.2.1 Soil VOCs

No VOCs were detected at concentrations exceeding the ESLs or HHSLs.

4.2.2.2 Soil SVOCs

Six SVOCs (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, benzo[g,h,i]perylene, benzo[k]fluoranthene, chrysene, dibenz[a,h]anthracene, indeno[1,2,3-cd]pyrene, and pyrene) were detected at concentrations exceeding the ESLs and or HHSLs. (see Figure 44). Background concentrations were not available for SVOCs in soil.

Surface Soil SVOC Results

Surface soil results for SVOCs are compared with ESLs and HHSLs below. Twenty-five surface soil samples were collected from 25 sample locations within the exposure area.

ESLs

Surface soil samples exceeded one or more of the ESLs at three (BWC-10, BWC-10A, and BWC-31) of the 25 surface soil sample locations. Specifically, pyrene exceeded its ESL (1,100 µg/kg) at all three locations; indeno(1,2,3-cd)pyrene exceeded its ESL (1,100 µg/kg) at two of the three locations; chrysene exceeded its ESL (1,100 µg/kg) at two of the three locations; and benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, and benzo(k)fluoranthene all exceeded their ESLs (1,100 µg/kg) at two of the three locations.

Residential RSLs

Surface soil samples exceeded one or more of the RSLs for residential soils at 14 of the 25 surface soil sample locations. Specifically, the following SVOCs were detected in surface soil samples exceeding one or more RSLs for residential soils: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene,

benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. Based on sample results, surface soil contamination from SVOCs begins at the eastern boundary of the exposure area, is localized to the southern portion of the exposure area, and extends to the western boundary.

Industrial RSLs

Surface soil samples exceeded one or more of the RSLs for industrial soils at seven of the 25 surface soil sample locations. Specifically, the following SVOCs were detected in surface soil samples exceeding one or more RSLs for industrial soils: benzo(a)pyrene and dibenz(a,h)anthracene. Benzo(a)pyrene was detected at all seven sample locations at concentrations ranging from 225 µg/kg to 1,630 µg/kg, exceeding its RSL of 210 µg/kg. Dibenz(a,h)anthracene was detected at two locations at concentrations ranging from 237 µg/kg to 341 µg/kg, exceeding its RSL of 210 µg/kg. Based on sample results, surface soil contamination from SVOCs begins at the eastern boundary of the exposure area, is localized to the southern portion of the exposure area, and extends to the western boundary.

Subsurface Soil SVOC Results

Subsurface soil sample SVOC results compared with HHSLs are discussed below. Thirty subsurface soil samples (greater than 2-feet bgs) were collected from 25 sample locations within the exposure area. Results for subsurface soil samples were not compared with ESLs.

Residential RSLs

One subsurface soil sample collected from 5 to 7 feet bgs at sample location BWC-23 exceeded the RSLs for residential soil for the following SVOCs: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and ideno(1,2,3-cd)pyrene. BWC-23 also exceeded the RSL for residential soil in its surface soil sample. A subsurface soil sample was collected from 10 to 12 feet at BWC-23 but SVOCs were not detected at concentrations above HHSLs. Based on these analytical data, subsurface soil contamination from SVOCs is limited to location BWC-23 from 2 to 7 feet bgs. BWC-23 is located at the eastern boundary of the exposure area.

Industrial RSLs

No subsurface soil samples were detected at concentrations that exceeded the RSL for industrial soils.

4.2.2.3 Soil Inorganic Compounds

Thirteen inorganic compounds (antimony, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, selenium, thallium, vanadium, and zinc) were detected at concentrations exceeding the ESLs, HHSLs, and or background concentrations, where available (see Figure 45).

Surface Soil Sample Inorganic Compounds Results

Surface soil results for inorganic compounds are compared with ESLs and HHSLs below. Twenty-five surface soil samples were collected from 25 sample locations within the exposure area.

ESLs

Surface soil samples exceeded one or more of the ESLs at all 25 surface soil sample locations. Specifically, the following inorganic compounds exceeded one or more ESLs and background concentrations when available: antimony, arsenic, chromium, cobalt, lead, manganese, , thallium, and vanadium,. Antimony, selenium and zinc were detected but not above background concentrations. Arsenic was detected in four surface soil samples at concentrations ranging from 24.4 mg/kg to 51.0 mg/kg, exceeding its ESL of 18 mg/kg and the background concentration of 15.8 mg/kg. The highest concentration of arsenic exceeding its ESL was detected at BWC-10. Chromium was detected in 12 surface soil samples at concentrations exceeding its ESL of 0.4 mg/kg and its background concentration of 20.8 mg/kg. Cobalt was detected in three surface soil samples at concentrations ranging from 14.4 mg/kg to 20.3 mg/kg, exceeding its ESL of 13 mg/kg; cobalt has no background concentration. Lead was detected in 11 surface soil samples at concentrations exceeding its ESL of 11 mg/kg and its background concentration of 17.1 mg/kg. Manganese was detected in five surface soil samples at concentrations exceeding its 220 mg/kg and its background concentration of 491.391 mg/kg. Thallium was detected at one sample location (BWC-57) at a concentration (1.6 mg/kg) exceeding its ESL of 1 mg/kg. No background concentration has been established for thallium in Marion County, nor was a background value established at the Union Tank Car site; therefore the locations that exceeded the ESL for thallium do not change with regards to background concentrations. Vanadium was detected in all 25 surface soil samples at concentrations ranging from 7.7 mg/kg to 61.5 mg/kg, exceeding its ESL of 2 mg/kg. Based on analytical results, surficial metal contamination in relation to ESLs exists throughout the entire exposure area.

Residential RSLs

Surface soil samples exceeded one or more of the RSLs for residential soils at all 25 surface soil sample locations. Specifically, the following inorganic compounds exceeded one or more ESLs: arsenic, iron,

and thallium. Arsenic results exceeded the RSL of 0.39 mg/kg and the background concentration of 15.8 mg/kg in six surface soil samples. These six surface soil samples are mainly located in the southeastern portion of the exposure area and at BWC-10, which is slightly northwest of the main grouping. Based on analytical results, arsenic is mainly observed in surface soils in locations within the southeastern portion of the exposure area as well as at BWC-36, located northwest of this grouping. Iron results exceeded the residential soil RSL of 55,000 mg/kg at one surface soil sample location (BWC-10A) with a concentration of 57,600 mg/kg; iron has no background concentration. Thallium results exceeded the RSL of 0.78 mg/kg one surface soil sample (BWC-57) at a concentration of 1.6 mg/kg; thallium has no background concentration.

Industrial RSLs

Surface soil samples exceeded one or more of the RSLs for industrial soils for arsenic. Arsenic results exceeded the RSL for industrial soil of 1.6 mg/kg and the background concentration of 15.8 mg/kg in six surface soil samples. These six surface soil samples are mainly located in the southeastern portion of the exposure area and at BWC-10, which is slightly northwest of the main grouping. Based on analytical results, arsenic is mainly observed in surface soils in locations within the southeastern portion of the exposure area as well as at BWC-36, located northwest of this grouping.

Subsurface Soil Sample Inorganic Compounds Results

Subsurface soil sample inorganic compounds results compared with HHSLs are discussed below. Thirty deep soil samples (greater than 2 feet bgs) were collected from 25 sample locations within the exposure area. Deep soil samples were not compared with ESLs.

Residential RSLs

Subsurface soil samples exceeded one or more of the RSLs for residential soils for arsenic and thallium. Arsenic results exceeded the RSL of 0.39 mg/kg and the background concentration of 15.8 mg/kg in 18 of the 30 samples. Thallium was detected in five subsurface soil samples (BWC-08, BWC-36, BWC-45, BWC-56, and BWC-57) at concentrations ranging from 0.81 mg/kg to 2 mg/kg, exceeding its residential soil RSL of 0.78 mg/kg; thallium has no background concentration.

Industrial RSLs

Subsurface soil samples exceeded one RSL for industrial soil for arsenic. Arsenic exceeded its RSL for industrial soil (1.6 mg/kg) and the background concentration of 15.8 mg/kg in 18 of the 30 samples.

Arsenic contamination in the deep soil samples encompasses the entire exposure area; however, concentrations of arsenic exceeding residential and industrial soil RSL and background are primarily detected from 2 to 12 feet bgs throughout the exposure area.

4.2.2.4 Groundwater VOCs

No VOCs were detected at concentrations exceeding the HHSLs.

4.2.2.5 Groundwater SVOCs

Four SVOCs (benzo[a]pyrene, benzo[b]fluoranthene, dibenzofuran, and naphthalene) were detected at concentrations exceeding the HHSLs (see Figure 46). Dibenzofuran was detected in one groundwater sample collected at temporary well BWC-GW07A at a concentration (6.1 µg/L) exceeding its RSL for tap water of 5.8 µg/L. This concentration also exceeds the established background range for dibenzofuran of 5.2 µg/L to 5.6 µg/L. The remaining SVOCs were detected in temporary monitoring well BWC-GW51. Benzo(a)pyrene was detected at a concentration of 0.024 µg/L, exceeding its RSL for tap water of 0.0029 µg/L; however, the concentration of benzo(a)pyrene did not exceed its MCL or the established background range of 5.2 µg/L to 5.6 µg/L. Benzo(b)fluoranthene was detected at a concentration of 0.042 µg/L, exceeding its RSL for tap water of 0.029 µg/L; however, the concentration did not exceed the established background range of 5.2 µg/L to 5.6 µg/L. Naphthalene was detected at a concentration of 0.21 µg/L, exceeding its RSL for tap water of 0.14 µg/L; however, the concentration did not exceed the established background range of 5.2 µg/L to 5.6 µg/L.

Therefore, only the concentration of dibenzofuran in temporary monitoring well BWC-GW07A exceeds its RSL for tap water and established background range. BWC-GW07A is located on the eastern border of the exposure area.

4.2.2.6 Groundwater Inorganic Compounds

Six inorganic compounds (aluminum, arsenic, cobalt, iron, lead, and manganese) were detected at concentrations exceeding the HHSLs (see Figure 47). Aluminum was detected in one temporary monitoring well (BWC-GW51) at a concentration of 17,400 µg/L, exceeding its RSL for tap water of 16,000 µg/L. This concentration also exceeds the established background range for aluminum of 164 µg/L to 3,390 µg/L. Arsenic was detected in six monitoring wells at concentrations ranging from 1.7 µg/L to 12.4 µg/L, exceeding its RSL for tap water of 0.045 µg/L. Arsenic also exceeded its MCL of 10 µg/L at one monitoring well location, BWC-GW51, with a concentration of 12.4 µg/L; however, these

concentrations do not exceed the established background range of 9.4 µg/L to 20 µg/L. Cobalt was detected in two monitoring wells (BWC-GW36A and BWC-GW51) at concentrations of 5.0 µg/L and 5.8 µg/L, exceeding its RSL for tap water of 4.7 µg/L. Both concentrations also exceed the established background range of 1.2 µg/L to 5.0. Iron exceeded its RSL for tap water (11,000 µg/L) at two sample locations (BWC-GW36A and BWC-GW51). Both concentrations (11,700 µg/L and 17,100 µg/L) also exceed the established background range of 60.7 µg/L to 3,720 µg/L. Lead was detected in one sample location, BWC-GW51, at a concentration of 18.3 µg/L, exceeding its MCL of 15 µg/L. This concentration also exceeds the established background range of 1.8 µg/L to 7.5 µg/L. Manganese was detected in one sample location, BWC-GW51, at a concentration of 325 µg/L, exceeding its RSL for tap water of 320 µg/L. This concentration also exceeds the established background range of 5.8 µg/L to 163 µg/L.

Based on this analytical data, inorganic compounds concentrations exceeding HHSLs and greater than the background range values primarily exist in temporary monitoring wells BWC-GW51, which is located near the eastern border of the exposure area and BWC-36A in the south-central part of the exposure area. Lead is the only metal that was detected at a concentration that exceeded its established MCL and background range. Arsenic also was detected at a concentration above its established MCL; however, the concentration was not above the established background range.

4.2.2.7 Product

As discussed in Section 2.0, soil borings were drilled and field screened using LIF technology to assess the potential presence of product (either LNAPL or DNAPL). Based on LIF screening results, DNAPL was suspected in the following boring locations; BWC-07A, BWC-07B, BWC-07C, BWC-08, BWC-08A, BWC-10A, BWC-31, and BWC-36A. Based on the wavelength frequencies obtained, a mixture of fuel (such as gasoline or diesel fuel) was suspected at these locations. LIF screening results are presented in Appendix D.

Based on LIF results, soil borings were drilled and soil samples were collected to obtain analytical results for surface and subsurface soil. During advancement of soil borings, product, staining, sheens, and odors were observed at several locations and various depths. Table 4-3 summarizes field observations during soil boring and sampling activities.

Table 4-3
Field Observations During Soil Boring and Sampling Activities – BWC-W

Boring Number	Depth (ft bgs)	Odor	Sheen	Staining	Product	Comments
BWC-07A	13-16	X				Fuel
BWC-08	11-12		X			Fuel
	14-15	X				Fuel
BWC-08A	10-13	X	X			Fuel
BWC-36A	8-10	X				Fuel

Of the four boring locations, all four had observable odors and two presented with the presence of a sheen. No staining or product was observed in any of the four boring locations.

During the August 2011, November 2011, and February 2012 investigations, an interface probe was used to collect water level measurements from existing temporary and permanent monitoring wells as well as to determine if product was present in any of the wells. Figures 48 through 56 presents those wells with observed products, sheens, or odors in at least one of the water level measurement events. Table 4-4 summarizes field measurements and observations.

Table 4-4
Observed Products, Sheen, or Odors During Water Level Measurement Events – BWC-W

Well ID	August 2011	November 2011	February 2012
Field Measurements and Observations			
BWC-GW07A	Strong fuel odor, sheen, and 0.11 foot of product	Fuel odor and sheen	Fuel odor and 0.11 foot of product
BWC-GW09	NA	Fuel odor and sheen	--
BWC-GW23	Slight fuel odor	--	--
BWC-GW36A	Fuel odor	Strong fuel odor and 0.5 foot of product	Strong fuel odor and 0.5 foot of product
BWC-GW51	NA	Fuel odor and sheen	--

During the August 2011 investigation, odors were observed at three temporary monitoring wells and a sheen or product was observed at one temporary monitoring well. Specifically, product was observed at temporary monitoring well BWC-GW07A. This temporary monitoring well is located west of the former bioremediation area, near the southern boundary of the site.

During the November 2011 investigation, odors were observed at four temporary monitoring well locations and a sheen or product was observed at all four temporary monitoring wells. Specifically, product was observed at temporary monitoring well BWC-GW36A. This temporary monitoring well is located along the southern boundary of the site, west of BWC-GW07A.

During the February 2012 investigation, odors were observed in two temporary monitoring well locations and a sheen or product was observed in the same two monitoring wells. Specifically, product was observed in temporary monitoring wells BWC-GW07A and BWC-GW36A. Both of these wells are located along the southern boundary of the site.

4.2.2.8 Exposure Area BWC-W Summary

Based on the analytical results for this exposure area, the following analytes were detected in various media exceeding one or more screening levels: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, dibenzofuran, ideno(1,2,3-cd)pyrene, naphthalene, aluminum, antimony, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, selenium, thallium, vanadium, and zinc. Soil and groundwater sampling results are summarized below.

Soil

No VOCs were detected at concentrations exceeding the ESLs or HHSLs. Analytes benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, ideno(1,2,3-cd)pyrene, pyrene, antimony, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, selenium, thallium, vanadium, and zinc were detected in soil samples at concentrations exceeding one or more screening levels and background concentrations, where available. In general, the majority of elevated results in soil samples with regards to SVOC contamination exceeded residential soil RSLs in surface soils. For this exposure area, 14 surface soil samples exceeded one or more RSLs for residential soils; seven surface soil samples exceeded one or more RSLs for industrial soils; and three surface soil samples from three sample locations (BWC-10, BWC-10A, and BWC-31) exceeded one or more ESLs. Based on sample results, surface soil contamination caused by PAHs begins

at the eastern boundary of the exposure area, stays to the southern portion of the exposure area, and extends to the western boundary.

Thirty deep soil samples (greater than 2-feet bgs) were collected from 25 sample locations within the exposure area. One deep sample collected at sample location BWC-23 exceeded the RSLs for residential soil for the following SVOCs: benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and ideno(1,2,3-cd)pyrene. Based on these analytical data, deep soil contamination by PAHs is limited to location BWC-23 from 2 to 7 feet bgs. BWC-23 is located at the eastern boundary of the exposure area.

With regards to inorganic compounds, surficial soil samples exceeded the ESLs at all sampling locations within the exposure area. With regards to HHSLs, surficial inorganic compound contamination, predominantly arsenic, is concentrated in the southeastern portion of the exposure area and also at BWC-36. Deep inorganic compound contamination with regard to HHSLs, predominantly arsenic and thallium, spans the entire exposure area, typically to a depth of 12 feet bgs.

When the established background concentration is factored in for arsenic (15.8 mg/kg), only 18 of the 30 samples still exceeded the residential and industrial RSLs and established background. Arsenic contamination in the deep soil samples encompasses the entire exposure area; however, concentrations of arsenic exceeding residential and industrial soil RSL and background are primarily detected from 2 to 12 feet bgs throughout the exposure area. Based on analytical results, contamination by inorganic compounds in the deep soils is spread throughout the entire exposure area.

Groundwater

Analytes benzo(a)pyrene, benzo(b)fluoranthene, dibenzofuran, naphthalene, aluminum, arsenic, cobalt, iron, lead, and manganese were detected in groundwater samples at concentrations exceeding one or more screening levels and background concentrations where available.

Four SVOCs (benzo[a]pyrene, benzo[b]fluoranthene, dibenzofuran, and naphthalene) were detected at concentrations exceeding the HHSLs. Dibenzofuran was detected in one groundwater sample collected at temporary well BWC-GW07A at a concentration (6.1 µg/L) exceeding its RSL for tap water of 5.8 µg/L. This concentration also exceeds the established background range for dibenzofuran of 5.2 µg/L to 5.6 µg/L. The remaining SVOCs were detected in temporary monitoring well BWC-GW51 but not at concentrations exceeding the established background ranges. Therefore, only the concentration of

dibenzofuran in temporary monitoring well BWC-GW07A contains an SVOC at a concentration exceeding its RSL for tap water and established background range. BWC-GW07A is located on the eastern border of the exposure area.

Six inorganic compounds (aluminum, arsenic, cobalt, iron, lead, and manganese) were detected at concentrations exceeding the HHSLs; however, once background values were taken into consideration, only the following metals exceeded both the RSL for tap water and established background range: aluminum in temporary monitoring well BWC-GW51, cobalt in temporary monitoring wells BWC-GW36A and BWC-GW51, iron in temporary monitoring wells BWC-GW36A and BWC-GW51, and manganese in temporary monitoring well BWC-GW51.

Lead was the only inorganic detected at a concentration exceeding its MCL and established background range. This concentration was detected at BWC-GW51.

Based on this analytical data, inorganic compounds contamination primarily exists in temporary monitoring well BWC-GW51, which is located near the eastern border of the exposure area, and BWC-36A, which is located near the south-central border of the exposure area.

Although SVOC contamination in groundwater was only detected in analytical data from location BWC-07A at concentrations exceeding both the RSL for tap water and upgradient concentration ranges, based on field observations while water level measurements were collected in November 2011 and February 2012, product was observed in BWC-GW36A. During the April 2011 sampling event when BWC-36A was sampled, analytical results did not indicate elevated SVOC concentrations; however, product was present during water level measurements collected after the April 2011 sampling event, and it is believed that the SVOC groundwater contamination now extends west to BWC-GW36A. SVOC contamination was not detected at concentrations exceeding both RSLs for tap water or MCLs and upgradient concentration ranges in any other wells; therefore, data indicate that SVOC contamination in groundwater is confined to the southern border of the exposure area, beginning with temporary monitoring well BWC-GW07A and continuing west to at least BWC-GW36A.

Based on LIF screening results, locations BWC-07A, BWC-07B, BWC-07C, BWC-08, BWC-08A, BWC-10A, BWC-31, and BWC-36A all presented with wavelength frequencies indicating the presence of product at the bedrock interface. Even though field observations during water level measurements may not have indicated the presence of product or odors, based on analytical results, all eight of these locations

in this exposure area have elevated concentrations of SVOCs in soils. In addition, the groundwater sample collected from BWC-GW07A indicated elevated concentrations of SVOCs, which is in line with the LIF screening results. In addition, although BWC-GW36A did not show elevated concentration of SVOCs in the analytical results, the LIF screening results further corroborate the presence of both LNAPL and DNAPL at this well. BWC-GW31 also indicted the presence of DNAPL based on LIF screening results. This well contained elevated concentrations of SVOCs in soils, indicating that although LNAPL may not be present, there could be DNAPL at the bedrock.

5.0 CONTAMINANT FATE AND TRANSPORT

This section discusses the physical and chemical properties of classes of chemicals identified at the LSR and BWC sites. The chemicals will be distinguished by the following classifications:

- PAHs – defined as any organic compound containing three or more aromatic rings
- VOCs – defined generally as any organic compound having a vapor pressure greater than 0.001 atmospheres.
- SVOCs – defined generally as any organic compound having a vapor pressure less than 0.001 atmospheres and consisting of no more than two aromatic rings
- Metals – defined as any metal or metalloid that may exist in elemental form or in any oxidized or reduced state.

Specifically discussed is how the chemical properties of these chemicals, in combination with the environment where they are located, affect constituent persistence and how these compounds behave in the natural environment.

Chemicals detected above screening levels and background concentrations, as appropriate, (as presented in Section 4.0) in any environmental medium are considered to be chemicals of interest (COI) in this section. Sections 5.1 to 5.3 provide general information on physiochemical factors influencing fate and transport, constituent persistence of the chemical class, and expected fate and transport for chemical constituent classes for both LSR and BWC. Section 5.4 discusses the potential routes of migration for LSR and BWC separately.

5.1 PHYSIOCHEMICAL FACTORS INFLUENCING FATE AND TRANSPORT

The fate and transport of the chemical classes depend on the following physiochemical properties of each constituent:

- Water solubility and molecular weight
- Organic carbon-water partitioning coefficient (K_{oc})
- Octanol-water partitioning coefficient (K_{ow})
- Vapor pressure
- Henry's Law constant
- Ionic charge
- Biological degradation
- Bioaccumulation factor

All of these properties influence a constituent's environmental persistence and the tendency of a constituent to migrate through the environment. The significance of each of these properties is discussed below.

5.1.2 Water Solubility and Molecular Weight

Solubility is the maximum concentration of a chemical that dissolves in any solvent at equilibrium conditions. Aqueous solubility is a critical property affecting the amount of constituent that will dissolve in groundwater. The higher a chemical's water solubility, the more likely it is to dissolve in and be mobile in the groundwater. Lower water solubility decreases a chemical's mobility and causes the chemical to stay adsorbed into soil surfaces. A chemical is assumed to have a high solubility when the solubility is greater than 1,000 ppm and low solubility when it is less than 10 ppm (Ney 1995).

Compounds that are present in groundwater at concentrations above the solubility limit may exist as a separate phase that will continue to contribute to soluble constituents in groundwater over time.

The aqueous solubility of a chemical is proportional to the chemical's ability to form hydrogen bonds with water molecules. In general, chemicals that contain an oxygen group (aldehydes, carboxylic acids, alcohols, ethers, ketones, and esters) are highly soluble in water because the oxygen group allows for hydrogen bonding with water. Cations and anions, including metals, are soluble in water because of their polar charge, which is either attracted to the oxygen or hydrogen in the water molecule. Positively charged cations are attracted to negatively charged oxygen atom of water and negatively charged anions are attracted to the positively charged hydrogen atoms. Organic compounds with an amine group (-NH_2) are also highly soluble because the amine is able to extract protons from water, which polarizes the amine (-NH_3^+) into a positively charged group that is attracted to the oxygen in the water molecule.

The pH of water can play an important role in solubility. This effect is more pronounced with organic acids and amines. Organic acids, such as phenols or carboxylic acids, lose a proton from their hydroxide (-OH) group at high pH conditions. The loss of the proton induces a negative charge (-O^-) on the compound, which makes it soluble in water because of the hydrogen bonding with water. However, phenols and carboxylic acids become less soluble at low pH. The solubility of amines in the water is also highly pH-dependent but by a different ionization mechanism. At high pH, there is a lack of available protons for the amine to extract so amines are more likely to remain the less soluble, non-polarized -NH_2 state. However, at low pH, amines are highly soluble since there is an abundance of protons to convert the -NH_2 group into the polarized -NH_3^+ group.

As the molecular weight of a non-polar organic increases, the water solubility decreases. The PAH chemical class will generally have low solubility because of the elevated molecular mass of the compounds. PAHs will not readily dissolve in the groundwater and consequently tend to stay adsorbed to the soils or in a liquid phase. SVOCs are moderately soluble because of their lower molecular weight when compared with PAHs. For example, the solubility of naphthalene and methylnaphthalene indicates these SVOCs may transport through the groundwater. VOCs have the smallest molecular weight of the three organic chemical classes and, therefore, will be the most soluble.

Metals become more soluble in groundwater as the pH of the groundwater is reduced. Their solubility increases as the groundwater acidity reacts with anions of insoluble metal salts to release the metals as soluble cations. As the pH of groundwater is raised, cations of metals like lead (Pb^{+2}), cadmium (Cd^{+2}), chromium (Cr^{+3}), zinc (Zn^{+2}), nickel (Ni^{+2}), iron (Fe^{+3}), and manganese (Mn^{+2}) will react with available hydroxides and or carbonates and become insoluble. In general, most metals will have very low solubility at pH values greater than 7.0. Anionic forms of metals like arsenate (AsO_4^{-3}) and arsenite (AsO_3^{-3}) are also more soluble at lower pH values since the acidity tends to dissolve cations from the salts that make the arsenite and arsenate insoluble at higher pH values. Higher ORP and higher pH values tend to retard the movement of both anionic and cationic dissolved metals and can also keep them from leaching out of soils when exposed to rainfall.

Some metals are amphoteric and will dissolve into water as anions at high pH values. The most notable are aluminum and lead. Aluminum exhibits its lowest solubility in the pH range of 5 to 7 and increases in solubility at higher pH values. Lead will typically begin to become soluble as an anion at pH values greater than 11.5. Similarly, oxyanions of arsenic (arsenite and arsenate), selenium (selenite), and vanadium (vanadate) will also increase in solubility at pH conditions above 12. An understanding of the amphoteric nature of these metals is important during the evaluation of remedial technologies in the FS if treatments that could substantially raise the pH of soil or groundwater are considered. However, under typical site conditions, amphoteric dissolution of metals is generally not a concern.

Soluble forms of the metals contaminants are relatively mobile, but other forms may adsorb to sediments or soils. The redox conditions in the soil may also have an important role in dictating the mobility of most of the inorganic contaminants. The soil pH will also affect the mobility of metals moving from the soil to groundwater with infiltrating precipitation or runoff.

Compounds from the SVOC and pesticide analyte groups tend to have limited mobility in the subsurface because of their tendency to sorb to soils. PAHs have a high sorption potential. Larger PAHs, which have four or more rings, such as benzo(a)pyrene and chrysene are expected to sorb more strongly to soils than PAHs that have two rings, such as naphthalene. The smaller PAHs tend to be more mobile. Rainwater percolating through soil could leach out PAHs with two rings and transport them to groundwater. Naphthalene is one of the most highly mobile PAHs found in soil. Solubility characteristics of PAHs vary for each PAH, but in general, it can be concluded that low molecular weight PAHs are more soluble and volatile and have less affinity for surfaces than do high molecular weight PAHs. Inorganic compounds are generally insoluble. Pesticides are more variable, though as a group they tend to be large compounds with low solubilities and high sorption potential.

5.1.3 Organic Carbon-Water Partitioning Coefficient

The soil organic carbon-water partitioning coefficient (K_{oc}) refers to the affinity of organics to be sorbed on to soil particles or sediment particles. K_{oc} is the ration of the mass of a chemical that is adsorbed in the soil per unit mass of organic carbon in the soil per the equilibrium chemical concentration in solution. It is the distribution coefficient normalized to total organic carbon content. K_{oc} values are useful in predicting the mobility of organic soil contaminants. Higher K_{oc} values correlate to less mobile organic chemicals, while lower K_{oc} values correlate to more mobile organic chemicals.

5.1.3 Octanol-Water Partitioning Coefficient

The octanol-water partitioning coefficient (K_{ow}) is the distribution of a chemical in octanol and water at equilibrium conditions. It represents the ratio of the concentrations of a chemical dissolved in octanol divided by the concentration of the chemical dissolved in water in a system at equilibrium conditions. The values are typically derived experimentally by adding a chemical into a well-mixed water and octanol system followed by measurement of the chemical concentration in each solvent after the solvents have separated. Chemicals with a greater affinity to dissolve in an organic solvent will have a higher K_{ow} , while chemicals with a greater affinity to dissolve in water will have lower K_{ow} values.

The K_{ow} is useful in determining how strongly a chemical is attracted to an organic solvent when compared with an aqueous solvent. This value is useful in interpreting how a chemical will react in a subsurface system that contains groundwater and LNAPL. A chemical having a high K_{ow} will be much more soluble in the LNAPL when compared with water and it will therefore have fewer tendencies to transfer from the LNAPL into the groundwater.

The equilibrium of how a chemical will dissolve in a system containing LNAPL and water is further complicated when a third phase, soil, is added to the equilibrium system. The K_{ow} is not only useful in determining how strongly a chemical is attracted to an organic solvent, but also how strongly the chemical will adsorb to organics (humics) that make up a portion of the soil. Chemicals with a higher K_{ow} value will have a stronger adsorption bond to the organic fraction of the soil and will therefore have fewer tendencies to desorb from soil.

A compound's K_{ow} can also be used to estimate the extent to which a given chemical is degraded by microorganisms. The K_{ow} value is used to calculate a chemical's bioconcentration factor (BCF) and the organic carbon partition coefficient. The higher the K_{ow} value, the lower the chemical's water solubility and mobility and the greater the tendency for increased bioconcentration. A low K_{ow} indicates the opposite — high water solubility and dissolved phase mobility with low soil sorption. K_{ow} values exceeding 1,000 ppm are considered to represent a high sorption potential, while values less than 500 ppm are considered to represent low sorption potential (Ney 1995).

In general, constituents with low vapor pressure and small molecular weight have low K_{ow} values and are not expected to bioaccumulate. VOCs and SVOCs typically have low to moderate K_{ow} value and therefore tend to be more mobile as dissolved-phase constituents in groundwater and also less likely to bioconcentrate in tissue. Typically, these compounds will bioattenuate within a few hundred feet of migration through the saturated soils by use of existing electron acceptors such as dissolved oxygen, ferric iron, and sulfate. The larger molecular weights and lower volatilization properties observed for PAHs correspond to a higher K_{ow} value and decreased mobility. As a result, PAHs tend to adsorb to soils and a number of larger PAHs are expected to bioaccumulate.

5.1.4 Vapor Pressure

Vapor pressure is a relative measure of a constituent's tendency to exist in equilibrium as a vapor at a specific temperature as opposed to existing as the chemical's pure state (solid or liquid) at that temperature. Of the chemical classes described in Section 5.1, VOCs and SVOCs are the only constituents with a measurable vapor pressure. A higher vapor pressure forces the VOCs or SVOCs to volatilize into the atmosphere. In general, VOCs have a vapor pressure greater than 0.001 atmosphere. Naphthalene is considered one of the most volatile SVOCs, yet it only has a vapor pressure of 0.0001 atmosphere at 25 degrees Celsius (Weast 1984). Therefore, VOCs are much more likely to migrate from soil by volatilization when compared with SVOCs. PAHs have vapor pressures less than 1×10^{-7}

atmospheres at ambient temperatures and therefore demonstrate negligible volatility. The vapor pressure of metals is also generally assumed to be negligible. For example, mercury is one of the most volatile metals, yet its vapor pressure is only 2×10^{-6} atmospheres at 20 degrees Celsius.

5.1.5 Henry's Law Constant

Henry's Law constant (H) relates a chemical's vapor pressure and its molar concentration. It states that, at equilibrium, a chemical's vapor pressure above a liquid is proportional to its molar concentration in the liquid. The relationship, in combination with the vapor pressure, defines the chemical's tendency to volatilize from water to the atmosphere. Henry's Law constant is calculated from the following equation:

$$H = (p/c)$$

where p is the vapor pressure and c is the molar concentration of the chemical.

Of the various chemical classes, VOCs and SVOCs are the only constituents with sufficient vapor pressures to calculate a Henry's Law constant. In addition to vapor pressure and solubility data, Henry's Law constant can indicate whether a chemical will dissolve into the groundwater or volatilize to the atmosphere. This relationship is important to fate and transport because it shows that as a compound's solubility increases, it will become less likely to volatilize from groundwater. In other words, the ability of a compound to volatilize from groundwater (volatility) is a function of both its vapor pressure and its solubility. For example, benzene has a vapor pressure of 0.1 atmosphere at a temperature of 20 degrees Celsius and a solubility of 22.8 millimoles/liter (mole/L) which calculates to a Henry's Law constant of $0.0044 \text{ atm}\cdot\text{m}^3/\text{mole}$ at a temperature of 20 degrees Celsius. Ethylbenzene has a vapor pressure of 0.009 atmosphere at a temperature of 20 degrees Celsius and a solubility of 1.43 mole/L, which calculates to a Henry's Law constant of $0.0063 \text{ atm}\cdot\text{m}^3/\text{mole}$ at a temperature of 20 degrees Celsius. Thus, even though ethylbenzene has a lower vapor pressure than benzene, it will have a higher tendency to volatilize in groundwater because of its higher Henry's Law constant. Constituents with a Henry's Law constant greater than $1 \times 10^{-5} \text{ atm}\cdot\text{m}^3/\text{mole}$ and a molecular weight less than 200 grams per mole are considered to be volatile (EPA 1989).

Because a chemical's solubility and vapor pressure change as a function of temperature, the Henry's Law constant for compounds also changes with temperature. Vapor pressure is much more temperature dependent than solubility, and vapor pressure increases as temperature increases. Therefore, the Henry's Law constant also increases with increasing temperature. The actual increase in Henry's Law constant as

a function of temperature can be calculated theoretically by dividing the vapor pressure of a specific compound at a specific temperature by its solubility at the same temperature.

5.1.6 Ionic Charge

Ions are atoms with electrical charges. Ionic charge indicates the number of electrons a specific atom needs to gain or lose to complete its valence and become electronically neutral. Ions with positive charges are cations, and ions with negative charges are anions. Ionic charge drives ion exchange, which is the sorption of ions in solution to surrounding soils.

Most metals in aqueous solution are cations. Clay soils provide charged surfaces to allow for cation exchange. Metals compete at these exchange sites and displace previously held cations under a process known as cation exchange. Sodium and calcium are the ions that are typically replaced from soils. Ions with the greatest electron affinity generally take precedence at soil exchange sites.

The capacity of soil to retain negatively charged ions (anions) is referred to as the soil anion exchange capacity (AEC). The quantity of anions that a soil can accommodate is typically expressed in terms of milliequivalents per 100 grams of soil (meq/100g). The AEC of most soils is in the range of 0.05 to 0.9 meq/100g, and most of the exchange occurs on the charged edges of minerals such as clay particles and iron oxides. Some anions sorb more strongly to these charges than other anions. The strength of the sorption bond is primarily dictated by the anionic charge.

It is important to understand that pH plays an important role in ion exchange, especially with respect to anion exchange. For example, although phosphate (PO_4^{-3}) and carbonate (CO_3^{-2}) are strongly adsorbed, they generally tend to react with cationic species at higher pH levels rather than under exchange mechanisms. Additionally, at neutral to slightly acidic pH conditions, these species will not exist and in the rightly charged state and instead will likely exist as HPO_4^{-2} and HCO_3^- . The charged state of the anion for arsenic, selenium, and vanadium are also a function of pH and ORP, so the charged state of these anions can change with environment.

5.1.7 Biological Degradation

Biological removal or transformation of organic chemicals by microorganisms in the soil is known as biodegradation. Biodegradation processes, which can occur aerobically or anaerobically, are influenced by available existing population of microbes, type of microbes, soil and groundwater pH, chemical

concentrations, available nutrients, available electron acceptors, and temperature (Ney 1995). In situations where the subsurface is limited by nutrients or electron acceptors, specific nutrients or electron acceptors can be added to increase the rate of biodegradation. For example, nitrate, phosphate, and sulfate are often injected into petroleum-contaminated groundwater to increase the degradation rates (phosphate is a nutrient, nitrate is both a nutrient and an electron acceptor, and sulfate is an electron acceptor).

The rates of degradation differ substantially depending on the type of constituent to be degraded. Biodegradation rate constants and half-life values can be used to determine if a constituent is readily degradable. Organic constituents that are insoluble in water and adsorbent in soil are unlikely to biodegrade. As the molecular weights of these organic constituents increase, the compounds become more stable and resistant to biodegradation. Consequently, VOCs and SVOCs more readily degrade, while PAHs degrade slowly. Bacteria generally convert these organic constituents into organic acids, which are further degraded over time into carbon dioxide and water.

Metals will not degrade, but a change in valence state may occur that may make the metal more or less soluble in groundwater. For example, ferric iron (Fe^{+3}) or manganic manganese (Mn^{+4}) may be used by bacteria as electron acceptors during degradation of VOCs or SVOCs, which converts the metals to more soluble valence states of ferrous iron (Fe^{+2}) and manganous manganese (Mn^{+2}). The metals are not biodegraded, but become more soluble in groundwater as part of the biodegradation process.

5.1.8 Bioturbation and Bioaccumulation Factor

Bioturbation is the displacement and mixing of sediment particles and solutes by fauna or flora. In aqueous environments, the sediment-water interface increases in area as a result of bioturbation, affecting chemical fluxes and thus exchange between the sediment and water column. Some organisms may further enhance chemical exchange by flushing their burrows with the overlying waters. Sediment bioturbation will generally improve degradation rates of organic compounds through oxygenation of surface sediments. Although bioturbation can have an effect on the anaerobic dechlorination of PAHs, it has little impact on the degradation rates of inorganic metals.

Bioaccumulation occurs in an organism when the uptake rate exceeds the organisms' ability to remove the chemical through metabolic functions, dilution, or excretion, so that the excess chemical is stored in the body of the organism. Many toxic organic chemicals attain concentrations in biota several orders of magnitude greater than their aqueous concentrations, and therefore, bioaccumulation poses a serious

threat to both the biota of surface waters and the humans that feed on these surface-water species (Smith 1988).

One result of bioaccumulation may be biomagnification of the chemical up the food chain.

Biomagnification occurs at the upper end of the food chain when the chemicals are passed from one organism to another through consumption. For example, phytoplankton contain low levels of PAHs, which are passed to the fish that eat the phytoplankton and ultimately to piscivorous birds or humans that eat the fish. However, the greater capacity of higher organisms to metabolize PAHs reduces the efficiency of the transfer. Species that do not metabolize PAHs at all or to only a limited extent, such as mollusks, accumulate high concentrations of PAHs, as would be expected from their high $\log K_{ow}$ values. However, organisms that metabolize PAHs such as fish and higher invertebrates accumulate little or no PAHs.

5.2 CHEMICAL CLASS CONSTITUENT PERSISTENCE

The extent to which constituents in each of the chemical classes will persist within the subsurface environment is significantly influenced by the constituent's physical and chemical properties and persistence and can be determined by a series of constituent removal mechanisms that influence fate and transport. These mechanisms include volatilization, attenuation (adsorption and ion exchange), and biodegradation.

5.2.1 Volatilization

Volatilization is a process that transfers chemical constituents from near-surface soils or water into soil gas or the atmosphere. Chemical volatilization is controlled by equilibrium processes that can be described in terms of vapor pressure for surface soils and Henry's Law constant for groundwater. The vapor pressure and Henry's Law constant of a compound will increase with increasing temperature, so volatilization is also directly influenced by temperature.

Vapor pressure, the pressure of a vapor in equilibrium with its non-vapor phases, indicates a chemical's tendency to exist in gaseous form as opposed to liquid or solid form. In general, organic compounds with a vapor pressure greater than 0.001 atmospheres are classified as VOCs and have a high potential to volatilize into the atmosphere rather than stay in the soil matrix. VOCs generally exhibit vapor pressures greater than 0.001 atmosphere. Some small SVOCs have vapor pressures in the range of 0.0001 to 0.001 atmosphere at 25 degrees Celsius (Weast 1984). PAHs and metals generally have a vapor pressure that is less than 1×10^{-7} atmospheres and therefore demonstrate little to no volatility.

The Henry's Law constant describes the ability of a chemical to volatilize from water into the air. Constituents with a Henry's Law constant greater than 1×10^{-5} atm-m³/mole and a molecular weight less than 200 grams per mole are considered volatile (EPA 1989). VOCs typically have a Henry's Law constant greater than 1×10^{-3} atm-m³/mole, while SVOCs generally have a Henry's Law constant in the range of 1×10^{-5} to 1×10^{-3} atm-m³/mole. The Henry's Law constants for PAHs and metals are very small, and loss of these constituents by volatilization is generally assumed to be negligible.

5.2.2 Sorption

Sorption refers to a constituent's tendency to be adsorbed or bound onto a solid matrix during transport through an aquifer. If a chemical is strongly adsorbed to the solid matrix, it will decrease significantly in dissolved-phase concentration as it is transported from the source. Sorption characteristics are quantified by a retardation factor (R_d). The R_d represents the relative velocity of the groundwater compared with the transport velocity of the sorbed chemical.

For organic compounds, the R_d is calculated using the following equation:

$$R_d = 1 + \rho_b/n \times K_d$$

Where ρ_b is the aquifer bulk density, n is the porosity and K_d is the distribution coefficient. The distribution coefficient is the ratio of concentrations in the solid and water phases and can be calculated using the following equation:

$$K_d = K_{oc} \times f_{oc}$$

Where K_{oc} is the organic carbon-water partition coefficient and f_{oc} is the organic carbon content.

Sorption of organics occurs in unsaturated soils as well as saturated soils. Therefore, as volatile and semivolatile compounds are vaporized from the groundwater, they will disperse into the unsaturated soils and adsorb onto the organic fraction of the soils. This adsorption typically occurs across the wetted interface of the soil where the compound is first sorbed into the wetted surface for the vapor phase and is then sorbed to the soil particle, but transfer from the vapor phase to the soil can also occur. This sorption mechanism from the vapor phase to the solid phase (and liquid phase) at the wetted surface can influence the persistence of these chemicals because vaporous dispersion is impeded by sorptive reactions in the vadose zone.

Retardation of metals in groundwater is associated both with precipitation reactions and ion exchange reactions. Precipitation reactions depend on the types of cations and anions that are dissolved in the water, the solubility constants for potential salts formed by the dissolved ions, and on the pH of the soil and groundwater system. However, ion exchange is one of the primary processes responsible for metals attenuation during transport through an aquifer. Ion exchange is a sorption mechanism that is not dependent on the organic content in the soil. Instead, it is associated with the amount and types of charged soil particles in the saturated zone. Dissolved metals are attracted to charged sites on the soil particles. When the metals attach to these charged sites, other less charged ions are in turn released from the soil such as sodium, potassium, calcium, or magnesium. The amount of metal that can be sorbed by ion exchange can be measured and it is reported in terms of ion exchange capacity. Clay minerals, zeolites, and oxido-hydrates are some types of minerals in the soil that provide for ion exchange of metals.

5.2.3 Biodegradation

Biological removal or transformation of organic chemicals performed by microorganisms in the soil, either aerobically or anaerobically, is known as biodegradation. Microbial population, type of microbes, soil or groundwater pH, chemical concentrations, available nutrients, available electronic acceptors, and temperature are all factors that influence biodegradation. Depending on the type of material being degraded, the rates of degradation differ substantially. Biodegradation rate constants and half-life values from literature can be used to determine if a constituent is likely to be readily degradable, but site-specific conditions exert the greatest influence on the rate of biodegradation that can be realized. Constituents such as PAHs, which are highly insoluble in water and highly adsorbent in soil, are unlikely to biodegrade quickly. For example, the literature value half-life for benzo(b)fluoranthene ranges from 1 to 1.67 years under aerobic conditions and between 3.95 to 6.68 years under anaerobic conditions. VOCs are more easily degraded because of their low molecular weight. For example, the literature value half-life for benzene ranges from 5 to 16 days under aerobic conditions and between 4 and 24 months under anaerobic conditions. SVOCs generally degrade at a similar rate as VOCs and much faster than PAHs. Metals are not biodegradable.

5.3 EXPECTED FATE AND TRANSPORT FOR CHEMICAL CONSTITUENT CLASSES

Constituents of the four chemical classes described in Section 5.1 have been identified at the LSR and BWC sites. The expected fate and transport of these constituent classes needs to be evaluated to identify the potential migratory routes and exposure pathways. The transport of these constituents is greatly influenced by the physiochemical characteristics of the individual chemical classes. While variances

exist, each of the constituents can be classified within one of four chemical classes (PAHs, VOCs, SVOCs, and metals). A general discussion on how the chemical characteristics exhibited by the constituent classes affect transport of the constituents through the environment is provided in the following sections.

5.3.1 Polycyclic Aromatic Hydrocarbons

PAHs are chemical compounds made up of three or more multiple fused unsubstituted aromatic rings that are formed by incomplete combustion of carbon-containing fuels. A list of PAHs of interest at both LSR and BWC are summarized below:

PAHs Retained as COIs – LSR

Anthracene	Benzo[g,h,i]perylene	Fluoranthene
Benzo[a]anthracene	Chrysene	Fluorene
Benzo[a]pyrene	Dibenzo[a,h]anthracene	Phenanthrene
Benzo[b]fluoranthene	Dibenzofuran	Pyrene
Benzo[k]fluoranthene		

PAHs Retained as COIs - BWC

Acenaphthene	Benzo[g,h,i]perylene	Dibenzofuran
Anthracene	Benzo[k]fluoranthene	Fluoranthene
Benzo[a]anthracene	Biphenyl	Ideno[1,2,3-cd]pyrene
Benzo[a]pyrene	Chrysene	Phenanthrene
Benzo[b]fluoranthene	Dibenz[a,h]anthracene	Pyrene

Compounds containing three or four fused aromatic rings are considered light PAHs. Examples of light or low molecular weight PAHs include anthracene with three aromatic rings and benzo(a)anthracene with four aromatic rings. PAHs with greater than four rings are referred to as heavy or high molecular weight PAHs. Examples of heavy PAHs with five aromatic rings include benzo(a)pyrene and benzo(b)fluoranthene. Heavy PAHs are generally more stable and less soluble and therefore are less likely to biodegrade and more likely to bioaccumulate. Light PAHs are generally slightly soluble, which makes them more susceptible to biodegradation. Most PAHs have a vapor pressure less than 1×10^{-10} atmospheres, so volatilization of PAHs is generally not a migration pathway.

PAHs encountered at LSR and BWC will generally remain immobile within the subsurface unless disturbed. The low solubilities and low vapor pressures exhibited by these compounds allow them to strongly adsorb to the soil and LNAPL, which mitigates the potential for downgradient migration but also decreases its availability for biodegradation. If dissolved macro-molecules or colloidal particles are present within the groundwater, these particles may contain adsorbed PAHs, which provide a transport

mechanism within the saturated zone along the groundwater gradient. PAHs adsorb readily to soil and may also be released into the atmosphere after soil is disrupted.

Because of their low solubility and high affinity for organic carbon, PAHs in aquatic systems are primarily found sorbed to particles that either have settled to the bottom or are suspended in the water column. It has been estimated that two-thirds of PAHs in aquatic systems are associated with particles and only about one-third are present in dissolved form (Eisler 1987). In surface water, PAHs can volatilize, photolyze, oxidize, biodegrade, bind to suspended particles or sediments, or accumulate in aquatic organisms (with bioconcentration factors often in the 10 to 10,000 range). In sediments, PAHs can biodegrade or accumulate in aquatic organisms (ATSDR 1995).

The major fate process for PAHs in water is adsorption to sediment or other organic matter. Sorption of PAHs to soil and sediments increases with increasing organic carbon content and with increasing surface area of the sorbent particles. Consequently, PAH concentrations in sediment and suspended matter are generally higher than in the associated water column.

The estimated Henry's law constants for low molecular weight PAHs indicate that volatilization may be a significant environmental transport process for those PAHs dissolved in natural water. However, adsorption to sediment significantly decreases the volatilization rate from the aquatic phase.

The rate and extent of biodegradation of PAHs in soil are affected by environmental factors; the organic content; structure and particle size of the soil; characteristics of the microbial population; the presence of contaminants such as metals and cyanides that are toxic to microorganisms; and the physical and chemical properties of the PAHs (Wilson and Jones 1993).

5.3.2 Volatile Organic Compounds

VOCs are characterized by higher vapor pressure, Henry's Law constant, and solubility when compared with the other chemical classes detected at both LSR and BWC. VOCs were not analyzed for in samples collected at LSR. A list of the VOCs of interest at BWC is summarized below:

VOCs Retained as COIs - BWC

Benzene
Ethylbenzene

The small molecular weight of VOCs, typically less than 130, and volatility characteristics indicate the tendency for VOCs to be highly mobile in the environment, but also facilitates breakdown and degradation of the VOCs (Ney 1995). The increased solubility allows for some VOCs to migrate within the groundwater before they attenuate by degradation or volatilization.

Benzene released to soil or waterways is subject to volatilization, photooxidation, and biodegradation. Biodegradation, principally under aerobic conditions, is an important environmental fate process for water- and soil-associated benzene. The high volatility of benzene is the controlling physical property in the environmental transport and partitioning of this chemical. Benzene is considered highly volatile with a vapor pressure of 95.2 mm Hg at 25 °C. Benzene is moderately soluble in water, with a solubility of 1,780 mg/L at 25 °C, and the Henry's law constant for benzene (5.5×10^{-3} atm-m³/mole at 25 °C) indicates that benzene partitions readily to the atmosphere from surface water (Mackay and Leinonen 1975). Since benzene is soluble in water, some minor removal from the atmosphere via wet deposition may occur. A substantial portion of any benzene in rain water that is deposited to soil or water will be returned to the atmosphere via volatilization.

Benzene released to soil surfaces partitions to the atmosphere through volatilization, to surface water through runoff, and to groundwater as a result of leaching. The soil organic carbon sorption coefficient (K_{oc}) for benzene has been measured with a range of 60 to 83 (Karickhoff 1981; Kenaga 1980), indicating that benzene is highly mobile in soil and readily leaches into groundwater. Other parameters that influence leaching potential include the soil type (sand versus clay), amount of rainfall, depth of the groundwater, and extent of degradation. In a study of the sorptive characteristics of benzene to solids in the groundwater aquifer, benzene showed a tendency to adsorb to aquifer solids. Greater soil adsorption was observed with increasing organic matter content (Uchrin and Mangels 1987). An investigation of the mechanisms governing the rates of adsorption and desorption of benzene by dry soil grains revealed that periods of hours are required to achieve equilibrium and that adsorption is much faster than desorption (Lin and others 1994). The rate of volatilization and leaching are the principal factors that determine overall persistence of benzene in sandy soils (Tucker and others 1986).

The large vapor pressure and Henry's law constant of ethylbenzene suggest a moderate to strong tendency for ethylbenzene to partition into the atmosphere, where it will exist predominantly in the vapor phase (Eisenreich and others 1981; Mackay 1979; Masten and others 1994). Depending on site-specific conditions, releases to surface soil can result in substantial losses to the atmosphere in addition to subsurface infiltration. Since it has a moderately high vapor pressure, ethylbenzene will evaporate fairly

rapidly from dry soil. Vapor phase transport will occur from subsurface releases (from leaking underground storage tanks) and during migration through unsaturated soil pore spaces (Rhue and others 1988). Atmospheric reaction with hydroxyl radicals can limit the atmospheric transport of ethylbenzene (Dewulf and van Langenhove 1997).

The large Henry's Law constant indicates that a significant proportion of ethylbenzene will partition from water into air (Mackay 1979; Masten and others 1994). Ethylbenzene dissolved in surface water, soil pore water, or groundwater will thus migrate into an available atmospheric compartment until its saturated vapor concentration is reached.

Based on log K_{oc} values in the range of 2.2 to 2.4, ethylbenzene is classified as having moderate mobility in soils. Sorption and retardation by soil organic carbon content will occur to a moderate extent, but sorption is not significant enough to completely prevent migration in most soils. Particularly in soils with low organic carbon content, ethylbenzene will tend to leach into groundwater. Mobility is also possible in aquifers that contain very little solid-phase organic matter, a condition common to sand and gravel aquifers (Ptacek and others 1984).

5.3.3 Semivolatile Organic Compounds

SVOCs are characterized by moderately low molecular weight, moderate to low volatility, and slight solubility. SVOCs are described as organic compounds having a vapor pressure less than 0.001 atmosphere and consisting of no more than two aromatic rings. A list of the SVOCs of interest at both LSR and BWC is summarized below:

SVOCs Retained as COIs – LSR

Bis(2-ethylhexyl)phthalate	2-Methylnaphthalene
3,3-Dichlorobenzidine	Naphthalene

SVOCs Retained as COIs - BWC

2-Methylnaphthalene	N-Nitrosodiphenylamine
Naphthalene	

In general, SVOCs are only slightly volatile, so volatilization is not considered a significant migration pathway. However, SVOCs tend to have a higher octanol-water partitioning coefficient and therefore sorb to fine soil and dust particles, which may represent a potential concern with respect to migration of dust particles. Although SVOCs are readily sorbed to soil, they are also readily degradable under proper

subsurface conditions. SVOCs have a moderately low molecular weight and some solubility, indicating transport of these compounds as dissolved-phase constituents within the groundwater is possible.

Naphthalene in the atmosphere is subject to a number of degradation processes, including reaction with photochemically produced hydroxyl radicals. Naphthalene has a short half-life in most natural waters and soils because of its tendency to volatilize and biodegrade. As a consequence of these processes, there is little tendency for naphthalene to build up in the environment over time.

Naphthalene released to the atmosphere may be transported to surface water or soil by wet or dry deposition. Since most airborne naphthalene is in the vapor phase, deposition is expected to be very slow (about 0.04 to 0.06 centimeters per second [cm/sec]). It has been estimated that about 2 to 3 percent of naphthalene emitted to air is transported to other environmental media, mostly by dry deposition (EPA 1982a).

Naphthalene in surface water may volatilize to the atmosphere. With a vapor pressure of 0.087 mm Hg at 25 EC, solubility in water of 31.7 mg/L at 20 EC, and a Henry's law constant of 4.6×10^{-4} (EPA 1982b), it is likely that volatilization is an important route of naphthalene loss from water. The rate of volatilization also depends on several environmental conditions, including temperature, wind velocity, and mixing rates of the air and water columns (EPA 1982a).

Log octanol/water partition coefficients (K_{ow}) for naphthalene range from 3.29 to 3.37 and log organic carbon coefficients (K_{oc}) range from 2.97 to 3.27 (Bahnick and Doucette 1988; EPA 1982b; Howard 1989; Klecka and others 1990; Thomann and Mueller 1987). Based on the magnitude of these values, it is expected that only a small fraction (less than 10 percent) of naphthalene in typical surface water would be associated with particulate matter (Thomann and Mueller 1987). Thus, naphthalene discharged to surface waters would remain largely in solution, with smaller quantities being associated with suspended solids and benthic sediments.

Naphthalene is easily volatilized from aerated soils (Park and others 1990) and is adsorbed to a moderate extent (10 percent) (Karickhoff 1981; Schwarzenbach and Westall 1981). The extent of sorption depends on the organic carbon content of the soil, with rapid movement expected through sandy soils (Howard 1989). The estimated soil adsorption coefficient for naphthalene in a soil with <0.6% organic carbon is 1.8 (Klecka and others 1990). Because it adsorbs to aquifer material (Ehrlich and others 1982), naphthalene's passage through groundwater will be somewhat retarded. However, sorption of naphthalene

to aquifer materials with low organic carbon content (less than 0.03 percent) may be enhanced by the presence of nonionic low-polarity organics, such as tetrachloroethene, commonly found at hazardous waste sites (Brusseau 1991).

BCFs for naphthalene have been measured and calculated from the K_{ow} , K_{oc} , or water solubility. The values reported for log BCF range from 1.6 to 3 (Banerjee and Baughman 1991; Bysshe 1982; Geyer and others 1982; Kenaga 1980; Southworth and others 1978; Veith and others 1979), indicating moderate bioconcentration in aquatic organisms. Naphthalene is reported to be rapidly eliminated from invertebrates when the organisms are placed in pollutant-free water (Eastmond and others 1984; Tarshis 1981), and naphthalene is readily metabolized in fish (Howard 1989). Based on the magnitude of the K_{ow} , bioaccumulation in the food chain is not expected to occur (Thomann 1989).

5.3.4 Metals

The major transport pathway for metals is in the form of dissolved ions in groundwater or adsorption and transport by adherence to soil particles either in water or in air. A list of metals of interest at both LSR and BWC is summarized below:

Metals Retained as COIs – LSR

Arsenic	Chromium (III)	Mercury
Antimony	Copper	Nickel
Beryllium	Cyanide	Silver
Cadmium	Iron	Zinc

Metals Retained as COIs - BWC

Aluminum	Chromium (III)	Mercury
Antimony	Cobalt	Nickel
Arsenic	Copper	Selenium
Barium	Iron	Thallium
Beryllium	Lead	Vanadium
Cadmium	Manganese	Zinc

Metals are not considered volatile under normal atmospheric conditions and pressure so vapor transport is not a concern. The primary migration pathway for metals is fine soil and dust particles with elevated metal concentrations that are released during site activities.

Metals transport in groundwater is influenced by the cationic or anionic charge of the metal and by pH. The solubility of cations such as lead, cadmium, and manganese is greatly influenced by groundwater pH, with increased solubility observed under lower pH conditions. Typically the solubility of metals increases exponentially as the pH falls below 6.0, although site-specific pH values are generally above this value. Metal cations become insoluble as the pH is raised because of charge reduction that occurs as the cation reacts with available hydroxide in the water. Eventually, cationic metals will precipitate out of solution as insoluble metal hydroxides or carbonates as the cationic charge is completely neutralized at higher pH values generally between 7.0 and 11.5. Higher ORPs tend to retard the movement of cationic dissolved metals and keep them from leaching from soil when exposed to rainfall since most cationic metals are less soluble in their higher state of oxidation.

Metals that may exist in the form of dissolved anions under normal pH conditions include arsenic (as arsenate $[H_2AsO_4^-]$ and arsenite $[H_2AsO_3^-]$, with arsenate having less mobility), selenium (primarily as the selenite anion SeO_3^{2-}), and vanadium (as the vanadate anion $H_2VO_4^-$).

Soils or media having high concentrations of carbonate or phosphate tend to provide for metals fixation. The carbonate creates neutral pH conditions that tend to retard migration of dissolved metals. Carbonates and phosphates both also tend to react with most cationic forms of metals to create insoluble precipitates.

Dissolved metals such as iron and manganese may be released into groundwater in areas where hydrocarbon impacts from bacteria utilizing these metals as electron acceptors. Although some metals like iron and manganese may be used in biological processes, the metals themselves cannot be biodegraded. As iron is dissolved into the groundwater, arsenic concentrations may also increase, partially from reducing groundwater conditions reducing the valence state of the arsenic and partially because the arsenic is often found in the subsurface bound to iron complexes.

5.4 POTENTIAL ROUTES OF MIGRATION

The subsurface geology, geochemical conditions within the soil or groundwater, and physiochemical parameters of the specific constituents all factor in with determining the routes of migration for the individual chemical classes through the subsurface. The following sections discuss migration of the various chemical classes through soil, groundwater, air and surface water. Section 5.4.1 will focus on LSR, and Section 5.4.2 will focus on BWC.

5.4.1 LSR Migration Routes

Figures 57 and 58 present the ecological and human health conceptual site models (CSM) for LSR. The primary source of contamination at the LSR site is river sediment that contains creosote or elevated levels of PAHs and metals as a result of industrial discharges from past wood treating operations at the BWC site.

Three primary release/transport (R/T) mechanisms have been identified during the RI and include:

- Suspension of contaminated sediment (and subsequent redeposition downstream)
- Dissolved-phase contamination in river water
- Leaching of contaminants from sediment to groundwater

Downstream sediment and surface water are considered the primary affected media.

Contaminants in sediment may either accumulate over time in depositional areas or be transported downstream as suspended solids. COIs are able to partition to sediment particles once discharged from a source into the environment. Chemicals adsorbed onto the sediments are primarily transported within the river system by physical processes. Important chemical and biological processes that facilitate uptake within the food chain include partitioning coefficients, metabolic processes, and species-specific bioaccumulation or bioconcentration factors.

Flowing water is the primary transport mechanism for movement of contaminated sediment in the LSR. Sediment transport is the primary mechanism for chemical movement in the LSR.

Surface water transport mechanisms depend on the type of water body present. In the LSR, the water velocity and sediment particle characteristics are the two main factors that influence the physical movement of sediment and the chemicals adsorbed onto their surfaces. The stream flow and sediment characteristics are discussed in Section 3.0.

Chemicals sorbed to sediments and organic matter may be transported in suspension or as bed load by river currents. Fine-grained material, such as silts and clays, will generally be entrained in the water column and migrate downstream as suspended solids. As water velocities increase during storm events or seasonal runoff, coarser-grained material (medium to coarse-grained sand or larger particles) will become suspended or move along the river bottom as bed load. Chemicals may accumulate as deposits as river velocities decrease. After deposition, bottom sediments are subject to resuspension.

If a chemical dissolves in surface water, its chemical transport properties will be identical to those of water. Compounds present as an immiscible liquid phase will either sink or float on water, depending on the compound's specific gravity. Nonaqueous-phase liquids with a specific gravity of less than 1 will tend to remain close to, or float on, the surface and may become susceptible to attenuation by volatilization and photolysis. Immiscible liquids more dense than water will move along the river bottom or become absorbed onto sediment particles.

Total organic carbon is a measure of one of the chemical components of organic matter that is often used as an indicator of its presence in a soil or sediment and is an important measurement since its presence can markedly influence how chemicals will react in the soil or sediment. TOC content is used to qualitatively assess the nature of the sampling location (for example, whether the area was depositional) or to normalize portions of the analytical chemistry data set (EPA 2002). In soils and sediments, there are three basic forms of carbon that may be present: (1) elemental, (2) inorganic, and (3) organic. The quality of organic matter in sediments is critical to the partitioning and bioavailability of sediment-associated contaminants. For example, Talley and others, 2002, demonstrated that although the majority of PAHs in a dredged sediment were found preferentially on coal-derived particles,, the PAHs on the clay/silt sediment fraction were more mobile and available, and thus potentially of greater concern. TOC results from samples collected during the RI indicate that TOC values range from 2.12 to 19.20. These data are used in the risk assessment to adjust the screening levels for organic constituents in sediments since toxicity is based on an equilibrium partitioning between sediment particles and interstitial water.

The AVS/SEM molar ratios are typically a better indicator of sediment toxicity than total metals concentrations on a dry weight basis. AVS is usually the dominant-binding phase for divalent metals in sediment. Metal sulfide precipitates are typically very insoluble, which limits the amount of dissolved metal available in the sediment porewater. For an individual metal, when the amount of AVS exceeds the amount of the metal (the SEM/AVS molar ratio is below 1), the metal concentration in the sediment porewater will be low because of the limited solubility of the metal sulfide. The sum of the SEM metals must be considered for a suit of divalent metals, with the assumption that the metal with the lowest solubility product (K_{sp}) value will be the first to complex with the AVS.

SEM/AVS testing is performed to determine the bioavailability and toxicity of metals in sediment. AVS is used to predict the toxicity in sediments of divalent metals, including copper, cadmium, nickel, lead, and zinc (Di Toro and others 1992; Ankley and others 1996; Berry and others 1996). The rationale is that the AVS present in a sediment reacts with the SEM, the reactive metal fraction that is measured in the

cold acid extract used to measure AVS. This reaction forms an insoluble metal sulfide that is relatively non-available for uptake by benthic organisms. The amount of AVS present in sediments will therefore serve a critical role in setting the limits of metal availability and toxicity in sediments.

As alluded to above, sulfide is an important binding component in modeling metal sorption in sediments (Boulegue and others 1982; Morse and others 1987). Metal sulfides are very insoluble. In the presence of excess sulfide, most of the reactive metal will form insoluble metal sulfides. It is therefore critical to quantify the available sulfide when evaluating the relationship between free aqueous phase metal and solid phase metal in sediments. AVS is a good measure of the portion of the solid phase sulfide that reacts with free metal (Di Toro and others 1990).

The five divalent metals, cadmium, nickel, copper, lead, and zinc, will bind to sulfide. As a result, in essence, they will all exist in the form of their respective metal sulfide if the AVS is present at a concentration in excess of the reactive forms of the sediment metals. In this case, only low free metal concentrations would be present in the pore water and available to cause toxicity to the organism. On the other hand, if the total concentration of the SEMs is greater than the concentration of AVS, the excess fraction of the metals may exist as free metal and could cause toxicity. It is stated that it could exist as free metal because other constituents in the sediment pore water (such as organic carbon) can bind the free metal, thereby reducing its availability to aquatic organisms and ultimately its toxicity.

The appropriate measure of the sediment metal concentration to use in comparing the concentration of sediment metals with AVS is the SEM concentration. As indicated above, SEM is the sum of all of the divalent metals that is extracted simultaneously with the sulfide in the analytical procedure used to measure AVS and is denoted as SEM. One mole of SEM will react with one mole of AVS for divalent metals. AVS results from samples collected during the RI indicate that AVS values range from 0.97 micromoles per gram ($\mu\text{moles/g}$) to 79.4 $\mu\text{moles/g}$. The calculated SEM/AVS ratios ranged from 0.040 to 0.89. Since all ratios are below 1, these ratios indicate that the inorganic compounds present in the sediment have limited bioavailability.

Sediment to Surface Water Pathway

LSR COIs have the potential to migrate to surface water by dissolution when adsorbed to sediment particles. Dissolution depends on the specific COI physicochemical factors described in this section.

Although sediment PAH contamination is prevalent throughout much of the LSR, bis(2-ethylhexyl)phthalate was the only organic analyte detected in surface water samples above screening levels. Therefore, dissolution of PAHs from sediment to surface water does not appear to be a significant migration pathway.

Cyanide, silver, and thallium were detected in surface water samples at concentrations greater than screening levels. However, only silver was also detected in sediment samples exceeding screening levels. Silver was also detected in surface water samples well upstream of the previous removal action in the LSR. Therefore, dissolution of inorganics from sediment to surface water also does not appear to be a significant migration pathway.

Suspension and Redeposition

LSR COIs have the potential to migrate downstream via surface water flow by suspension and become redeposited. Suspension and redeposition depend on the specific COI physicochemical factors described in this section.

COIs are present in sediment at concentrations above screening levels throughout the LSR. Sediment samples collected within the previous removal area indicate that sediments above screening levels are present within this stretch of the LSR. Significant suspension and redeposition have occurred in this area. No visual signs of creosote, odors, or sheens were observed in this stretch of the LSR. The presence of COIs within the previous removal action could be attributed to residual contamination above RI screening levels, redeposition from upstream areas, or runoff from roads and higher land into the LSR. Sediment samples collected both upstream and downstream of the previous removal area indicate that flow reversals could also be transport mechanisms. Sediment and surface soil samples collected from adjacent low-lying areas contained COIs at concentrations above screening levels, indicating that river flooding and overtopping its banks may also be transport mechanisms.

Sediment to Biota (Bioaccumulation)

COI concentrations exceeding screening levels in both sediment and biota samples (fish and invertebrates) are evidence of bioaccumulation. Although fish and humans are able to metabolize PAHs, the concentrations are elevated enough to be above HHSLs in fish. Given that fishing is common downstream within the Scioto River and is accessible within the LSR near road crossings, sediment to biota is a viable pathway.

Sediment to Groundwater

One concern after Ohio EPA's ESI was that there was a potential for contamination to migrate from sediment to shallow groundwater adjacent to the river. Temporary groundwater monitoring wells were installed adjacent to the LSR and sampled to evaluate this potential migration pathway. The results indicate that PAHs were not present in groundwater and that only some inorganic COIs are present in shallow groundwater at concentrations exceeding screening levels. However, the majority of these elevated results were from samples collected from the temporary monitoring well cluster at State Route 95, which is located by a landfill. Analytical results from the adjacent sediment sample located in this area contained levels of inorganic COIs typical throughout the LSR. In addition, based on results of the groundwater investigation, water levels measured over a 3-week period varied less than one-tenth and up to four-tenths of a foot at the upstream location, indicating that the relationship between the groundwater and LSR appears to be based on location. At Keener Pike and Holland Road, the LSR appears to be a losing stream (the river is a recharge boundary for groundwater), while at State Route 95 and State Route 739, the LSR appears to be a gaining stream (the river is a discharge boundary for groundwater). Based on the analytical results and the variable relationship between groundwater and the LSR, migration of contaminants in sediment to shallow groundwater does not appear to be a significant migration pathway.

Air

The sediment and surface water to air pathways are not considered likely because of the nature and low probability of volatilization of COIs. Therefore, the air pathway is not a viable pathway.

5.4.2 BWC Migration Routes

Figures 57 and 59 present the ecological and human health CSMs for BWC. The primary source of contamination at the BWC site includes spills, leaks, waste, or other releases resulting from past wood treating operations. Contaminants detected during the RI and previous investigations include elevated levels of PAHs, VOCs, and metals. Given the contaminant concentrations detected and visual evidence of creosote-contaminated soils, creosote still exists at the BWC site as NAPL.

Primary R/T mechanisms have been identified during the RI and include:

- Volatilization
- Fugitive emissions
- Runoff
- Erosion
- Leaching of contaminants from soil to groundwater

Ambient air, surface soil, subsurface soil, and groundwater are considered the primary affected media.

Soil Exposure Pathway

Contaminants in soil may either bind to the soil or leach to groundwater. Contaminants in soil may also be taken up through food webs.

Elevated concentrations of PAHs and metals were detected in the unsaturated soils above the water table throughout the site, but especially within and directly north and east of the former bioremediation area. Initial surface releases could result in infiltration or leaching through the soils as the constituents move downward toward the water table. The most likely constituent classes to reach the groundwater are the SVOCs described in Section 5.3.2. The PAHs described in Section 5.3.3 are more likely to sorb to soil before they reach the groundwater and are therefore more likely to remain in shallow soils, but can be carried to depth with the movement of LNAPLs because of their high solubility in the LNAPL. It is plausible that the PAHs are moving with the LNAPL and not remaining stagnant in the shallow soils, since product was observed at deeper depths below the water tables, because LNAPL was observed at the BWC site. In this situation, the LNAPL would include pure hydrocarbons (petroleum products), lighter halogenated solvents, or both. DNAPL would include the heavier halogenated solvents. The phenolic fraction of creosote is more soluble in water and would tend to move with the water, while the PAH fraction of creosote is more soluble in the LNAPL or DNAPL and would tend to move with the NAPL. The inorganic compounds identified in Section 5.3.4 are likely to attenuate on soil by ion exchange within the unsaturated soil matrix before they reach the water table. Exceptions include iron, manganese, arsenic, selenium, and vanadium, since they may be dissolved from the soils by reducing conditions created by hydrocarbon degradation.

Elevated concentrations of PAHs and inorganic compounds were also detected in the saturated soils within and directly north and east of the former bioremediation area. The PAHs and SVOCs detected in the saturated soils will generally adsorb to the soil and have limited mobility in the saturated zone.

Groundwater Migration Pathway

Once in groundwater, contaminants may (1) migrate laterally if continuous permeable materials are present, or (2) migrate vertically from the unconsolidated deposits to the limestone bedrock.

Migration through groundwater is a potential pathway at BWC and is thought to be the primary migration pathway of concern. Site VOCs are soluble and mobile and would be expected to migrate downgradient, most likely in a dissolved phase. Site SVOCs are considered less mobile and soluble based on their higher molecular weights and the fact that they are more likely to adsorb to the soils; however, they still have the potential to migrate through the subsurface to groundwater. Site PAHs have low solubilities and are less likely to migrate in groundwater. The migration of metals depends on the pH and ORP conditions. Based on groundwater quality readings collected during sampling, the pH in site groundwater is neutral, ranging between 6.0 and 8.0 at most locations. Neutral pH conditions limit the ability of metals to transport through groundwater; therefore, metals at BWC are not expected to easily move through groundwater.

The majority of PAH and metal contamination in groundwater is located within and east of the former bioremediation area. Similar constituents were detected in both soils and groundwater, suggesting that migration from soil to groundwater is occurring, especially at location BWC-GW22, where various metals at elevated concentrations were detected in both soil and groundwater but nowhere else on the site.

Based on comparing analytical results from the shallow monitoring wells and temporary wells installed in the unconsolidated materials to the four monitoring wells installed in the limestone bedrock, it appears that vertical migration from shallow groundwater to bedrock groundwater is not a significant pathway.

Based on visual observations, contamination is migrating west, as was identified in temporary well BWC-GW36A. When it was originally installed and a water level collected, no product was observed. During the second round of water level measurements, a slight sheen and fuel odor were observed; then, during the next two readings, approximately 0.5 foot of product was observed in the well. These observations indicate that (1) site-related contamination is moving westward in groundwater, (2) contamination from an off-site source may be migrating onto the western part of BWC, or (3) a smear zone may exist at the groundwater/vadose zone interface and the presence of product in BWC-GW36A may be a result of a rise or fall in groundwater elevation.

Migration from Surface Runoff

Ground surface elevations at the BWC site range from 923.1 feet to 936.2 feet, with the higher ground surface elevations measured on the eastern portion of the site. In general, surface runoff would move from east to west, following the slope of the land. Surface soils are contaminated with PAHs and metals at concentrations exceeding one or more screening levels or established background. Based on the

elevation data, it is possible that surface soil contamination on the eastern portion of the property could migrate to the western portion of the property. The former bioremediation area is more contaminated than other areas and is located within the eastern portion of the property. Although a berm exists on the eastern, western, and southern borders of the former bioremediation area, the berm is mainly composed of sandy materials that may allow chemicals to migrate. In addition, samples were collected directly outside of the perimeter of the former bioremediation area and sample results indicate the presence of PAHs and metals at elevated concentrations, possibly indicating that the berm is not completely effective in preventing contamination from migrating.

A slag pile also exists on the eastern portion of the property. Sample results indicate the presence of PAHs and metals at elevated concentrations within the pile. Although some of the pile is immobile (very hard material), individual small pieces of slag capable of migrating via air or from runoff were observed and also included in the sample. A sample of the surrounding surface soils also indicated the presence of similar constituents at elevated concentrations, suggesting the slag pile has had some contribution to contamination of the surrounding soils. Materials from the slag pile could also migrate via rain runoff to the surrounding soils, causing elevated concentrations in surrounding soils.

Based on field observations and analytical data, migration of surface soils and the slag pile contamination may be a pathway at the site as a result of surface runoff.

Surface Water Migration Pathway

Other than puddles and standing water that may exist after periods of heavy rainfall, surface water bodies are not present at BWC. Therefore, surface water samples were not collected at BWC during the RI.

Migration of contamination from the BWC property to nearby surface water bodies is possible by airborne deposition, groundwater migration, and surface runoff, but is unlikely. Airborne deposition for PAHs and metals to surface water occurs when constituents migrate into the air onto fugitive dust particles and then later settle in the surface water. PAHs and metals may also travel to surface water via the groundwater. VOCs and SVOCs may migrate to surface water in groundwater as dissolved constituents or by precipitation events that scrub the constituents from the air and deposit them into the surface water.

Surface water samples and groundwater samples were collected at locations directly west of the BWC site at the LSR, in the direction of groundwater flow. Low levels of a few metals were detected in the

temporary monitoring well cluster on Holland Road and one PAH was detected above its screening level in surface water. However, the concentrations do not indicate that contamination from BWC is migrating to LSR via air, groundwater, or surface runoff. In addition, during the previous removal action, the drain tiles running from BWC to North Rockswale Ditch were sealed and analytical results indicate that this seal is still effectively preventing migration from BWC to NRD and subsequently to LSR.

Air Migration Pathway

Fugitive emissions in air may be deposited from air back to surface soil. VOCs detected in groundwater have the potential to migrate into the air via groundwater or through LNAPL. Both benzene and ethylbenzene would readily volatilize from groundwater based on their high Henry's Law constants. Site SVOCs are less volatile but still have the potential to release to air via groundwater. Site PAHs and metals do not significantly volatilize; however, they can be adsorbed to soil and dust particles and therefore could be released to the air by wind.

The slag pile contains elevated concentrations of PAHs and metals; however, it is unlikely that material from the pile (other than very small pieces) would become airborne and deposit on other areas of the property. There could be some slight air migration from surface soils. Most surface soils in the area of the former bioremediation area are sandy and fine-grained material could be picked up by the wind and transferred to other areas of the site.

Migration of Constituents from LNAPL

The presence of LNAPL has been confirmed within certain areas of the site, primarily within and directly east of the former bioremediation area, but also along the southern border of the site at locations BWC-GW07A and BWC-GW36A. Surface soils are more permeable and would lend themselves to the mobility of LNAPL; however, after the first few feet, the majority of the soil becomes a silty clay that would make the LNAPL relatively immobile within the subsurface. Sand seams have been observed and would lend themselves as a migration route for the LNAPLs to reach groundwater and bedrock. LNAPLs and water do not mix; therefore, they must share pore space in the upper groundwater zone. The LNAPLs will spread laterally until they fill the available pore space and then movement will stop. If the LNAPL is composed of a lighter, more soluble, chemical, there is the potential that the lighter chemical could split from the LNAPL and enter groundwater because the phenolic fraction of creosote is more soluble in water and would move with the water, while the PAH fraction of creosote is more soluble in the NAPL and would tend to move with it.

Based on sample results, it is highly likely that constituents from LNAPLs have migrated to groundwater as well as through sand seams to reach the bedrock surface. This migration was confirmed by the LIF screening, where a majority of product and or DNAPL was observed sitting right above or at the bedrock interface.

6.0 HUMAN HEALTH RISK ASSEMENT SUMMARIES AND CONCLUSIONS

The following sections present summaries and conclusions for the LSR and BWC HHRA. Additional information can be found in Appendix L.

6.1 LSR AND BWC HUMAN HEALTH RISK ASSESSMENTS

The following sections discuss the HHRA objectives, exposure areas, approach, results, and a summary of overall conclusions for the LSR and BWC sites.

6.1.1 Objectives

The LSR and BWC HHRA's evaluate the current and potential future health risks and hazards associated with exposure to site-related chemicals of potential concern (COPC) at the LSR and BWC sites. The primary objectives of the HHRA's are as follows:

- To determine if site-related constituents detected in environmental media pose unacceptable risks to current and future human receptors under baseline (unremediated) conditions.
- To provide information to support decisions concerning the need for further evaluation or action based on current and reasonably anticipated future land use.

6.1.2 Exposure Areas

To conduct the HHRA's, each site was subdivided into exposure areas, primarily on the extent of historical sediment removal and visual evidence of remaining contamination (LSR) and the location of historical industrial activities and the distribution of soil contamination (BWC). The exposure areas for the LSR and BWC HHRA's are presented below.

6.1.2.1 LSR Exposure Areas

The LSR site was subdivided into six exposure areas: LSR-DWN1, LSR-DWN2, LSR-DWN3, LSR-DWN4, LSR-ALL, and LSR-UP1. The six exposure areas are shown in Figure L-1-2 (in Appendix L) and are defined as follows:

- LSR-DWN1 – this exposure area includes the portions of the LSR and NRD addressed during the previous removal action.
- LSR-DWN2 – this exposure area includes the portion of the LSR where visual contamination has been previously observed.
- LSR-DWN3 – this exposure area includes the portion of the LSR down to the confluence with the Scioto River where no visual contamination has been observed.

- LSR-DWN4 – this exposure area includes the ditches and waterways adjacent to LSR including Rockswale and Columbia Ditches.
- LSR-ALL – this exposure area includes LSR-DWN1, -DWN2, and DWN3 considered as a whole. This additional exposure area was created for the HHRA to handle fish and mussel samples that were collected at various points along the LSR.
- LSR-UP1 – this exposure area includes the portion of the LSR and NRD upgradient of the previous removal action.

In addition, low-lying surface soil samples were collected along the LSR. The surface soil samples do not in themselves represent an exposure area, but instead were assigned to the exposure area along which they were collected.

6.1.2.2 BWC Exposure Areas

The BWC site was subdivided into two primary exposure areas. These areas are: BWC-E and BWC-W. In addition, for the purposes of the HHRA, a third exposure area, BWC-N, was created to serve as a surrogate for adjacent off-site farm land. The three exposure areas are shown in Figure L-1-4 (in Appendix L) and are defined as follows:

- **BWC-E:** BWC-E represents the eastern portion of the BWC property containing the former processing area.
- **BWC-W:** BWC-W represents the western portion of the BWC property containing the former drying area.
- **BWC-N:** BWC-N represents sampling locations along the northern and western boundaries of the BWC site. EPA was unable to access the adjacent farmland north and west of the BWC site. Because of their location at the boundaries of the BWC site, the sample locations within the BWC-N exposure area provide a conservative estimation of farmland north and west of the BWC site that may have become contaminated from the transport of site contaminants off-site through erosion, overland flow, and fugitive dust generation.

Also, for the purposes of the HHRA, a fourth exposure area (BWC-BKG) was created to represent soil and groundwater unimpacted by site activities. Background soil samples (surface soil only) were collected from the Union Tank Car site, located south across Holland Road, from the BWC site (see Figure L-1-4 in Appendix L). The soil background data set was approved for use as the BWC soil background data set by the Ohio EPA and EPA Region 5 Remedial Project Manager via email on October 31, 2012. Similarly, a series of five shallow groundwater wells (BWC-TW-25, BWC-TW-28, BWC-TW-54, BWC-TW-55, and BWC-MW2-S) located along the northern border of the BWC site and judged to be unimpacted by site activities were selected as representative of background groundwater conditions (see Figure L-1-6 in Appendix-M). The background soil and groundwater locations were collectively considered as a single exposure area, BWC-BKG.

6.1.3 HHRA Approach

Consistent with standard risk assessment practice and EPA guidance (EPA 1989), the LSR and BWC HHRA include the following components: (1) data evaluation and selection of COPCs, (2) exposure assessment, (3) toxicity assessment, and (4) risk characterization.

Medium-specific data sets used to prepare the LSR and BWC HHRA consisted of analytical data collected during the RI. These data are considered the most up-to-date available and provide reasonable geographic coverage. It was conservatively assumed that conditions at the time of the RI (i.e., unremediated conditions) are representative of current and future conditions. COPCs were selected following EPA guidance (primarily EPA's "Risk Assessment Guidance for Superfund [RAGS; EPA 1989) based on (1) screening of maximum detected concentrations against medium-specific screening levels selected as the most conservative values from EPA's RSLs and (2) elimination of essential nutrients.

As defined in RAGS (EPA 1989), the four elements necessary to form a complete exposure pathway include:

- A source or release from a source,
- A mechanism of release and transport,
- A point of contact for potential receptors, and
- An exposure route.

If any one of the four elements is missing, the exposure pathway is incomplete. In general, only potentially complete exposure pathways were evaluated in the HHRA. The LSR and BWC human health CSM are diagrammatically presented in Figures L-1-7 and L-1-8, respectively, and summarized in the Risk Assessment Guide for Superfund Part D (RAGS D) Tables 1-1 and 1-2 in Appendix L-1 (see Appendix L to this report).

Briefly, historical operations at and discharges from the BWC site are felt to be the source of contamination in the LSR. More specifically, a combined sanitary and storm sewer was located along the southern border of BWC along Holland Road. The combined sewer traveled west beneath Holland Road and discharged into NRD. Sewer tie-ins from the BWC property were the likely transport mechanism for creosote discharging off of the BWC property. NRD flows west approximately 0.5 mile before discharging into LSR.

Additionally, contaminants in surface soil may have migrated off site and impacted adjacent farmland through erosion, surface water run-off, and redeposition of fugitive dusts. Finally, contaminants in soil and slag may have leached to groundwater. Volatile in groundwater may subsequently migrate to ambient air or into buildings through vapor intrusion.

Once the contaminants were discharged into the NRD and subsequently the LSR, contaminants were transported downstream along with surface water flow, via suspension and redeposition of sediment and dissolution from sediment into surface water. As demonstrated by the presence of various contaminants in fish and mussel tissues, contaminants may be taken up into various food webs.

The receptors and exposure routes considered quantitatively or qualitatively in the LSR and BWC HHRA include the following:

LSR Receptors and Exposure Routes

- ***Current and Future Recreationalist:*** Current and future anglers were assumed to be exposed to sediment and surface water in the LSR via incidental ingestion and dermal contact and to surface soil via incidental ingestion, dermal contact, and inhalation of fugitive dusts and vapors.
- ***Current and Future Farmers:*** Current and future farmers were assumed to be exposed to sediment and surface water in the LSR via incidental ingestion and dermal contact and to surface soil via incidental ingestion, dermal contact, and inhalation of fugitive dusts and vapors.
- ***Future Residents:*** Future residents were assumed exposed to floodplain soil at LSR-DWN2 and LSR-DWN3 via incidental ingestion, dermal contact, and inhalation of particulates and vapors.
- ***Current and Future Fish Consumer:*** Current and future fish consumers were assumed to be exposed via ingestion of fish tissue (fillets) from the LSR.
- ***Current and Future Mussel Consumer:*** Current and future mussel consumers were assumed to be exposed via ingestion of mussel tissue from the LSR.
- ***Future Utility Worker:*** Future utility workers were assumed to be exposed to sediment and surface water in the LSR via incidental ingestion and dermal contact and to surface soil via incidental ingestion, dermal contact, and inhalation of fugitive dusts and vapors.

BWC Receptors and Exposure Routes

- ***Current and Future Trespasser:*** Current and future trespassers were assumed to be exposed via incidental ingestion of, dermal contact with, and inhalation of particulates and vapors from surface soil and subsurface soil throughout the BWC site.
- ***Current and Future Farmer:*** Current and future farmers are assumed to be exposed via incidental ingestion of, dermal contact with, and inhalation of particulates and vapors from surface soil immediately off-site and adjacent to the BWC site. Theoretically, farmers may also be exposed via ingestion of produce grown in these off-site soils. However, any exposure via

this pathway is expected to be minimal relative to other direct contact exposure pathways. Therefore, this exposure pathway is evaluated only qualitatively.

- **Future Resident:** Future residents were assumed to be exposed via incidental ingestion of, dermal contact with, and inhalation of particulates and vapors surface and subsurface soil and ingestion of produce grown in surface and subsurface. Also, residents may be exposed via ingestion of and dermal contact with groundwater used as a source of potable water and via inhalation of vapors that have migrated from groundwater to indoor air.
- **Future Recreationalist:** Future recreationalists were assumed to be exposed via incidental ingestion of, dermal contact with, and inhalation of particulates and vapors from surface and subsurface soil.
- **Future Commercial/Industrial Worker:** Future commercial/industrial workers were assumed to be exposed via incidental ingestion of, dermal contact with, and inhalation of particulates and vapors from surface and subsurface soil and via ingestion of groundwater used as a source of potable water and via inhalation of vapors that have migrated from groundwater to indoor air.
- **Future Construction Worker:** Future construction workers were assumed to be exposed via incidental ingestion of, dermal contact with, and inhalation of particulates and vapors from surface and subsurface soil and via inhalation of VOCs from site (Note: the water table at the site is at 8 to 10 feet bgs, which is close to the typical depth of construction trenches. Therefore, groundwater was assumed to enter construction trenches and construction workers were assumed to have direct contact with groundwater).
- **Future Utility Worker:** Future utility workers were assumed to be exposed via incidental ingestion of, dermal contact with, and inhalation of particulates and vapors from surface and subsurface soil and via inhalation of VOCs from site (Note: the water table at the site is at 8 to 10 feet bgs, which is close to the typical depth of utility trenches. Therefore, groundwater was assumed to enter utility trenches and utility workers were assumed to have direct contact with groundwater).

Receptor-specific intakes for each exposure route were calculated under both reasonable maximum exposure (RME) and central tendency exposure (CTE) conditions using equations and exposure parameter values presented in the RAGS Part D 4 Series tables (included as part of Appendix L-1 – see Appendix L).

In addition to the exposure parameter values presented in Appendix L-1, the equations also included a medium-specific concentration that receptors were assumed to be exposed to. This concentration is referred to as the exposure point concentration (EPC). In general, EPCs were calculated as the 95 percent UCL on the mean using EPA's ProUCL Version 4.1.00 statistical software package (EPA 2010). The EPC was generally selected as the 95 percent UVCL of the statistical method recommended by ProUCL. Construction workers and utility workers are expected to be exposed in limited portions of each exposure area. Therefore, consistent with EPA recommendations, the maximum detected concentration was used as the EPC for these receptors. Groundwater also presents unique circumstances that complicate the calculation of EPCs. Receptors are not expected to be exposed to groundwater from multiple locations

across an exposure area. Rather, receptors may ingest groundwater from a single wells installed at a particular location or may have direct contact with groundwater in a construction trench at a particular location. As a result, EPCs for groundwater were calculated as follows. For the evaluation of potential exposure to groundwater at the BWC site, one to three proximal wells considered representative of the center of the “plume” or area of consistently elevated concentrations at each exposure area (BWC-E and BWC-W) and at each depth (shallow and deep) were identified. As noted in Section 2.3.1.1 of Appendix L, statistical treatment was not conducted for constituents with less than eight detected results. In this circumstance, the maximum detected concentration was used as the groundwater EPC. This approach is conservative because current and future receptors may not always be exposed in the area of the wells used to calculate exposure area- and depth-specific groundwater EPCs. To the extent that receptors are exposed elsewhere in the exposure area, risks and hazards may be over- or underestimated.

Modeling was used to generate medium-specific EPCs for media not sampled directly. Specifically, modeling was used to estimate EPCs for blood lead, trench air, indoor air, and homegrown produce as summarized below.

- EPA’s Integrated Exposure Uptake Biokinetic (IEUBK) Model (EPA 2009j) and the Adult Lead Model (ALM) (EPA2009 b) were used to estimate receptor-specific lead screening levels.
- The concentrations of VOCs from groundwater in outdoor air within a construction or utility trench were estimated using a methodology developed by the Virginia Department of Environmental Quality (VDEQ) as part of its “Voluntary Remediation Program Risk Assessment Guidance” (VDEQ 2008).
- The migration of VOCs from underlying groundwater into indoor air (subsurface vapor transport) was evaluated consistent with EPA guidance, including ‘Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)’ (EPA 2002) and “User’s guide for Evaluating Subsurface Vapor Intrusion into Buildings” (EPA 2004). EPA’s Johnson and Ettinger model (Version 3.1) also was used.
- The uptake of COPCs from soil into homegrown produce was evaluated using the methodology from EPA’s “Human Health Risk Assessment Protocol (HHRAP) for Hazardous Waste Combustion Facilities” (EPA 2005i).

The risk assessment used the default toxicity values presented in the EPA Regional Screening Level (RSL) tables (EPA 2012a). The default values were obtained from the following sources in the order in which they are presented below:

- Integrated Risk Information System (IRIS) on-line database (EPA 2012c)
- Provisional Peer Reviewed Toxicity Values (PPRTV) derived by EPA’s Superfund Health Risk Technical Support Center for the EPA Superfund Program

- The Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRL) (ATSDR 2012)
- The California Environmental Protection Agency/Office of Environmental Health Hazard Assessment's toxicity values (CalEPA 2003)
- Screening toxicity values in appendices to certain PPRTV assessments
- The EPA Superfund Program's Health Effects Assessment Summary Tables (HEAST) (EPA 1997c)

Toxicity values used in the HHRA are presented in Tables 5.1 and 5.2 (non-cancer toxicity values) and Tables 6.1 and 6.2 (cancer toxicity values) of Appendix L-1 (see Appendix L).

EPA's IEUBK model and ALM were used to assess potential risks associated with exposure to lead for residents and non-residents, respectively (EPA 2003, 2009a, and 2009b). Specifically, the EPA default resident RSL of 400 mg/kg was determined to be the appropriate (or conservative surrogate) lead screening level for residents, trespassers, and recreationalists (EPA 2012). The EPA default industrial/commercial RSL of 800 mg/kg was determined to be the appropriate lead screening level for industrial/commercial workers. Receptor-specific lead soil screening levels for construction and utility workers were developed under both RME and CTE conditions using EPA's ALM and receptor-specific exposure parameters as described in Section 2.3.1.2. As discussed in that section, the following construction worker and utility worker lead soil screening levels were developed:

- Construction workers: 930 mg/kg (RME) and 2,016 mg/kg (CTE)
- Utility workers: 4,716 mg/kg (RME and CTE conditions)

6.1.4 HHRA Results

The following sections summarize the risk assessment results and conclusions for the LSR and BWC sites.

6.1.4.1 LSR HHRA Summary and Conclusions

Total and COPC-specific risks and hazards under RME conditions for each of the LSR exposure areas are discussed below in Sections 2.7.1.1 (LSR-DWN1), 2.7.1.2 (LSR-DWN2), 2.7.1.3 (LSR-DWN3), 2.7.1.4 (LSR-DWN4), 2.7.1.5 (LSR-ALL), and 2.7.1.6 (LSR-UP1). At the separate in-stream exposure areas (LSR-DWN1, -DWN2, -DWN3, DWN4, and -UP1), five different receptors were evaluated: child recreationalist, adolescent recreationalist, adult recreationalist, adult farmer, and adult utility worker. Also, at LSR-DWN2 and LSR-DWN3, a child and aggregate resident receptors were evaluated. For LSR-ALL, six different receptors were evaluated: child, adolescent, and adult fish consumers and child,

adolescent, and adult mussel consumers. Risks for the LSR exposure areas are summarized in Tables L-2-2 through L-2-7 (see Appendix L).

LSR-DWN1

LSR-DWN1 includes those portions of the LSR and NRD that were addressed during the previous removal action. Total hazards for all receptors are less than 1 and considered insignificant. Similarly, total risks for the adult farmer and adult utility worker are less than $1\text{E-}06$ and considered insignificant. Finally, total risks for child recreationalists ($1.2\text{E-}05$), adolescent recreationalists ($2.9\text{E-}06$), and adult recreationalists ($4.4\text{E-}06$) are at the low end of EPA's target risk range of $1\text{E-}06$ to $1\text{E-}04$. These risks are driven by potential exposure to benzo(a)pyrene and benzo(a)pyrene equivalents (BaPE) in sediment. No significant risks are associated with potential surface water exposure, except for the current and future adult recreationalist ($1.2\text{E-}06$) – no surface water COCs was identified.

LSR-DWN2

LSR-DWN2 includes those portions of the LSR with historical visual contamination. Total hazards for all receptors are less than 1 and considered insignificant, except for the child resident ($\text{HI} = 5.1$) – driven by antimony. Total risks for all recreational and residential receptors are greater than $1\text{E-}04$ (the upper end of EPA's target risk range): child recreationalists ($8.9\text{E-}04$), adolescent recreationalist ($1.9\text{E-}04$), adult recreationalist ($1.9\text{E-}04$), and aggregate resident ($1\text{E-}03$). Total risks for adult farmers ($4.2\text{E-}05$) and adult utility workers ($4.1\text{E-}05$) are within EPA's target risk range. All total risks are driven by potential exposure to individual carcinogenic PAHs and BaPE in sediment, with minor contributions from arsenic. These same COPCs are also present in soil. However, the risks associated with potential exposure to soil are about one order of magnitude lower than those associated with potential exposure to sediment. No significant risks are associated with potential surface water exposure.

LSR-DWN3

LSR-DWN3 includes those portions of the LSR with no historical visual contamination down to the confluence with the Scioto River. Total hazards for all receptors are less than 1 and considered insignificant, except for the child resident ($\text{HI} = 6.4$) – driven by antimony and arsenic. Total risks for all receptors (except for the aggregate resident) are within EPA's target risk range and go from $1.2\text{E-}05$ (adult farmer) to $8.8\text{E-}05$ (child recreationalist). The total risk for the aggregate resident is $3.5\text{E-}04$. The total receptor-specific risks at LSR-DWN3 are about 3 to 7 times lower than at LSR-DWN2. The risk drivers are the same as for LSR-DWN2, with one primary exception. A single potentially carcinogenic PAH, indeno(1,2,3-cd)pyrene, was identified as a COPC in surface water at LSR-DWN3. The risk associated with potential exposure to indeno(1,2,3-cd)pyrene in surface water equaled or exceeded

potential exposure to BaPE in sediment. Because sediment concentrations in LSR-DWN3 are less than at LSR-DWN2, the presence of indeno(1,2,3-cd)pyrene in surface water at LSR-DWN3 is unusual. It may represent an aberrant condition, possibly related to back-flow from the Scioto River.

LSR-DWN4

LSR-DWN4 includes portions of waterways (including Rockswale and Columbia Ditches) that are adjacent to the LSR and drain into the LSR at the upstream end of LSR-DWN3. Total hazards for all receptors are less than 1 and considered insignificant. Total risks for all receptors are similar to those found at LSR-DWN1 and are near the low end of EPA's target risk range for the recreational receptors (9.9E-06 [child recreationalist], 2.2E-06 [adolescent recreationalist], and 3.2E-06 [adult recreationalist]) and less than 1E-06 and considered insignificant for adult farmers and adult utility workers. As for LSR-DWN1, the risk drivers at LSR-DWN4 are BaPE in sediment.

LSR-ALL

LSR-ALL represents all of LSR (LSR-DWN1, -DWN2, and -DWN3). Fish and mussel samples were collected from various locations throughout these exposure areas. Six receptors were evaluated for this exposure area: child, adolescent, and adult fish consumers and child, adolescent, and adult mussel consumers.

Total hazards are less than 1 and considered insignificant for all receptors, with one exception. The total hazard for the child fish consumer is 1.3 and is driven by potential exposure to thallium. Total risks for fish consumers are all at the low end of EPA's target risk range: 1.2E-06 (child fish consumer), 1.4E-06 (adolescent fish consumer), and 5.3E-06 (adult fish consumer). These risks are driven by potential exposure to arsenic and BaPE. Total risks for mussel consumers are 20 to 50 times higher than for fish consumers and are within or slightly above EPA's target risk range: 5.1E-05 (child mussel consumer), 6.1E-05 (adolescent mussel consumer), and 1.4E-04 (adult mussel consumer). These risks are driven by potential exposure to BaPE and to a less extent, hexavalent chromium.

It should be noted that field personnel observed no evidence of recreational fishing (including mussel collection). The fish species taken from the LSR are primarily bottom-feeders and a more recreationally attractive stream, the Scioto River, is located immediately adjacent to the LSR. Finally, it is not certain that enough mussels are present in the LSR to support the recreational mussel ingestion assumed for this HHRA.

LSR-UP1

LSR-UP1 includes portions of LSR and NRD upgradient of the previous removal action. Total hazards are less than 1 and considered insignificant for all receptors. Total risks are less than 1E-06 and

considered insignificant for the adolescent recreationalist, adult farmer and adult utility worker. Total risks for child and adult recreationalists and all mussel consumers are at the low end of EPA's target risk range, with the highest risk for adult mussel consumers ($1.7E-05$). It should be noted that the total risks for mussel consumers are about one order of magnitude less than for LSR-ALL.

Overall LSR HHRA Conclusions

The following conclusions were drawn for the LSR HHRA:

- Total hazards are less than 1 and considered insignificant for all receptors with the following exceptions; the total hazard for the child fish consumer is 1.3 (driven by potential exposure to thallium) and child resident at LSR-DWN2 (HI = 5.1; driven by antimony) and LSR-DWN3 (HI = 6.4; driven by antimony and arsenic).
- Total risks are less than $1E-06$ and considered insignificant or at the low end of EPA's target risk range (less than $1E-05$) for the adult farmer and adult utility worker.
- Total risks exceed $1E-04$ (the upper end of EPA's target risk range) for all recreational receptors in LSR-DWN2, adult mussel consumers in LSR-ALL, and aggregate residents at LSR-DWN2 and LSR-DWN3. All other risks are within EPA's target risk range.
- Risks are driven primarily by potential exposure to BaPE (and individual potentially carcinogenic PAHs) in sediment. The primary exception are risks associated with potential exposure to indeno(1,2,3-cd)pyrene in surface water in LSR-DWN3. Risks associated with potential exposure to soil at LSR-DWN2 and -DWN3 are about one order of magnitude lower than the risks associated with potential exposure to sediment in the same areas.
- Total risks in the in-stream segments from highest to lowest are as follows:
 - LSR-DWN2
 - LSR-DWN3
 - LSR-DWN1 and LSR-DWN4
 - LSR-UP1
- Primary uncertainties relate to (1) the representativeness of the indeno(1,2,3-cd)pyrene detected in surface water at LSR-DWN3 and (2) the assumptions regarding fish and mussel consumption from LSR-ALL – do individuals regularly fish the LSR and are sufficient mussels present to support the assumed mussel consumption.
- Finally, the risks and hazards calculated under CTE conditions are about 2 to 12 times lower than those calculated under RME conditions depending on the receptor considered.

6.1.4.2 BWC HHRA Summary and Conclusions

Total and COPC-specific risks and hazards under RME conditions for each of the BWC exposure areas are discussed below. At BWC-E, BWC-W, and BWC-BKG, nine different receptors were evaluated: current and future adolescent and adult trespassers; future residents; future child, adolescent, and adult recreationalists; future industrial/commercial workers, future construction workers, and future utility

workers. For BWC-N, only the current and future adult farmer was evaluated. Risks for the BWC exposure areas are summarized in Tables L-2-8 through L-2-11 (see Appendix L).

BWC-E

BWC-E represents the eastern portion of the BWC property containing the former processing area. BWC-E is currently unoccupied, but may be redeveloped in the future. Risks and hazards for each of the receptors evaluated for this exposure area are summarized in Table L-2-8 (see Appendix L) and discussed below.

Current and Future Adolescent and Adult Trespassers

Adolescent and adult trespassers were evaluated only under current land use conditions. While trespassing may continue to occur in the future, it was assumed that other more regularly exposed receptors (for example, residents or industrial/commercial workers) would be protective of potential trespassers). No significant hazards were identified. Total risks for both the adolescent and adult trespassers ($6.3\text{E-}05$ and $6.5\text{E-}05$, respectively) are within EPA's target risk range and are driven by potential exposure to BaPE in surface soil.

Future Residents

Residents were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to surface and subsurface soil (assuming homes could be built using slab-on-grade construction [surface soil] or with basements, requiring excavation [subsurface]) and shallow and deep groundwater (allowing for variable depth of future groundwater well construction).

Total hazards exceed 1 under all soil and groundwater combinations: 180 (surface soil [SS]/shallow groundwater [SG]), 39 (SS/deep groundwater [DG]), 180 (sediment benchmark [SB]/SG), and 39 (SB/DG). The medium-specific total hazards are as follows: SS (38) – driven by several metals and naphthalene; SB (39) – same drivers, with greater naphthalene concentration and with dibenzofuran and 2-methylnaphthalene; SG (135) – driven by arsenic, naphthalene, dibenzofuran, 2-methylnaphthalene, and manganese, as well as other metals and organics; and DG (0.88) – insignificant.

Total risks exceed $1\text{E-}04$, the upper end of EPA's target risk range, by two orders of magnitude for all soil and groundwater combinations: $5.6\text{E-}02$ (SS/SG), $4.7\text{E-}02$ (SS/DG), $2.9\text{E-}02$ (SB/SG), and $1.9\text{E-}02$ (SB/DG). The medium-specific total risks are as follows: SS ($4.7\text{E-}02$) – driven by BaPE and arsenic; SB ($1.9\text{E-}02$) – driven by BaPE and arsenic; SG ($8.5\text{E-}03$) – driven by BaPE, arsenic, and several VOCs; and DG ($4.7\text{E-}05$) – driven by arsenic.

Future Child Recreationalists

Child recreationalists were evaluated only under future land use conditions and assumed potential exposure to surface soil (no intrusive activity) and subsurface soil (assuming intrusive activity in developing the recreational space). Total hazards are less than 1 and considered insignificant for both surface (0.52) and subsurface (0.36) soil.

Total risks exceed $1\text{E-}04$, the upper end of EPA's target risk range, assuming potential exposure to surface soil ($5.3\text{E-}04$) assuming potential exposure to subsurface soil ($1.6\text{E-}04$). Risks are driven by potential exposure to BaPE and to a less extent, arsenic.

Future Adolescent Recreationalists

Adolescent recreationalists were evaluated only under future land use conditions and assumed potential exposure to surface soil (no intrusive activity) and subsurface soil (assuming intrusive activity in developing the recreational space). Total hazards are less than 1 and considered insignificant for both surface ($6.1\text{E-}02$) and subsurface ($5.4\text{E-}02$) soil.

Total risks are within EPA's target risk range, assuming potential exposure to surface soil ($6.3\text{E-}05$) and subsurface soil ($2.6\text{E-}05$). Risks are driven by potential exposure to BaPE.

Future Adult Recreationalists

Adult recreationalists were evaluated only under future land use conditions and assumed potential exposure to surface soil (no intrusive activity) and subsurface soil (assuming intrusive activity in developing the recreational space). Total hazards are less than 1 and considered insignificant for both surface ($5.9\text{E-}02$) and subsurface ($4.7\text{E-}02$) soil.

Total risks are within EPA's target risk range, assuming potential exposure to surface soil ($6.5\text{E-}05$) and subsurface soil ($2.7\text{E-}05$). Risks are driven by potential exposure to BaPE.

Future Industrial/Commercial Workers

Industrial/commercial workers were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to surface and subsurface soil and shallow and deep groundwater (as described above for residents).

Total hazards exceed 1 only when potential exposure to shallow groundwater is assumed: 7.8 (SS/SG), 0.85 -- insignificant (SS/DG), 7.8 (SB/SG), and 0.79 -- insignificant (SB/DG). The medium-specific total hazards are as follows: SS (0.72) -- insignificant; SB (0.67) -- insignificant; SG (7.1) -- driven by dibenzofuran and naphthalene; and DG (0.13) -- insignificant.

Total risks exceed $1\text{E-}04$, the upper end of EPA's risk range, under all soil and groundwater combinations: $7.1\text{E-}04$ (SS/SG), $5.8\text{E-}04$ (SS/DG), $3.8\text{E-}04$ (SB/SG), and $2.5\text{E-}04$ (SB/DG). The medium-specific total hazards are as follows: SS ($5.7\text{E-}04$) – driven by BaPE and arsenic; SB ($2.4\text{E-}04$) – driven by BaPE and arsenic; SG ($1.3\text{E-}04$) – driven by arsenic, BaPE, 1-methylnaphthalene, and several VOCs; and DG ($1.1\text{E-}05$) – driven by arsenic.

Future Construction Workers

Construction workers were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to subsurface soil and shallow groundwater (construction workers would never encounter deep groundwater due to limits on the depth of any excavation).

Total hazards significantly exceed 1, at $9.9\text{E+}02$. The medium-specific hazards are as follows: SB (2.7) – driven by potential inhalation exposure to naphthalene (1.2) in a construction trench and SG ($9.8\text{E+}02$) – driven by potential inhalation exposure to naphthalene (890), 1,1'-biphenyl (85), dibenzofuran (5.2), and benzene (1.5) in a construction trench.

Total risk ($3.4\text{E-}04$) exceeds $1\text{E-}04$, the upper end of EPA's target risk range. The medium-specific risks are as follows: SB ($6.9\text{E-}06$) – driven by BaPE and SG ($3.3\text{E-}04$) driven by potential inhalation exposure to naphthalene ($3.2\text{E-}04$) in a construction trench.

Future Utility Workers

Utility workers were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to subsurface soil and shallow groundwater (utility workers would never encounter deep groundwater due to limits on the depth of any excavation).

Total hazard (76) exceeds 1. Medium-specific hazards are as follows: SB (0.12) – insignificant and SG (76) – driven by potential inhalation exposure to naphthalene (68) and 1,1'-biphenyl (6.5) in a construction trench.

Total risk ($2.6\text{E-}03$) exceeds $1\text{E-}04$, the upper end of EPA's target risk range. The medium-specific risks are as follows: SB ($4.7\text{E-}05$) – driven by BaPE and arsenic and SG ($2.5\text{E-}03$) driven by potential inhalation exposure to naphthalene ($2.5\text{E-}03$) and BaPE ($3.3\text{E-}05$) in a construction trench.

BWC-W

BWC-W represents the western portion of the BWC property containing the former drying area. BWC-W is currently unoccupied, but may be redeveloped in the future. Risks and hazards for each of the receptors evaluated for this exposure area are summarized in Table L-2-9 (see Appendix L) and discussed below.

Current and Future Adolescent and Adult Trespassers

Adolescent and adult trespassers were evaluated only under current land use conditions. While trespassing may continue to occur in the future, it was assumed that other more regularly exposed receptors (for example, residents or industrial/commercial workers) would be protective of potential trespassers). No significant hazards were identified. No significant risks were identified except for the adult trespasser ($1.7\text{E-}06$), driven by arsenic.

Future Residents

Residents were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to surface and subsurface soil (assuming homes could be built using slab-on-grade construction [surface soil] or with basements, requiring excavation [subsurface]) and shallow and deep groundwater (allowing for variable depth of future groundwater well construction).

Total hazards exceed 1 under all soil and groundwater combinations: 15 (SS/SG), 5.9 (SS/DG), 16 (SB/SG), and 5.9 (SB/DG). The medium-specific total hazards are as follows: SS (5.5) – driven by antimony and cobalt; SB (5.8) – similar drivers; SG (9.9) – similar drivers; and DG (0.43) - insignificant.

Total risks exceed $1\text{E-}04$, the upper end of EPA's target risk range, for all soil and groundwater combinations: $8.8\text{E-}04$ (SS/SG), $4.7\text{E-}04$ (SS/DG), $7.8\text{E-}04$ (SB/SG), and $3.7\text{E-}04$ (SB/DG). The medium-specific total risks are as follows: SS ($4.3\text{E-}04$) – driven by BaPE and arsenic; SB ($3.2\text{E-}04$) – driven by BaPE and arsenic; SG ($4.5\text{E-}04$) – driven by BaPE and arsenic; and DG ($4.5\text{E-}05$) – driven by arsenic.

Future Child Recreationalists

Child recreationalists were evaluated only under future land use conditions and assumed potential exposure to surface soil (no intrusive activity) and subsurface soil (assuming intrusive activity in developing the recreational space). Total hazards are less than 1 and considered insignificant for both surface (0.2) and subsurface (0.22) soil.

Total risks at the low end of EPA target risk range, assuming potential exposure to surface soil ($5.5\text{E-}06$) and subsurface soil ($3.8\text{E-}06$). Risks are driven by potential exposure to BaPE.

Future Adolescent Recreationalists

Adolescent recreationalists were evaluated only under future land use conditions and assumed potential exposure to surface soil (no intrusive activity) and subsurface soil (assuming intrusive activity in developing the recreational space). Total hazards are less than 1 and considered insignificant for both surface (0.21) and subsurface (0.24) soil.

Total risks are less than $1\text{E-}06$ and considered insignificant assuming potential exposure to surface soil ($8.1\text{E-}07$) and subsurface soil ($6.8\text{E-}07$).

Future Adult Recreationalists

Adult recreationalists were evaluated only under future land use conditions and assumed potential exposure to surface soil (no intrusive activity) and subsurface soil (assuming intrusive activity in developing the recreational space). Total hazards are less than 1 and considered insignificant for both surface (0.21) and subsurface (0.24) soil.

Total risks slightly exceed $1\text{E-}06$ assuming potential exposure to surface soil ($1.7\text{E-}06$) and subsurface soil ($1.6\text{E-}06$).

Future Industrial/Commercial Workers

Industrial/commercial workers were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to surface and subsurface soil and shallow and deep groundwater (as described above for residents).

Total hazards exceed 1 only when potential exposure to shallow groundwater is assumed: 1.6 (SS/SG), 0.32 -- insignificant (SS/DG), 1.6 (SB/SG), and 0.34 -- insignificant (SB/DG). The medium-specific total hazards are as follows: SS (0.25) -- insignificant; SB (0.27) -- insignificant; SG (1.3) -- no drivers; and DG (0.065) -- insignificant.

Total risks are within EPA's target risk range, under all soil and groundwater combinations: $7.7\text{E-}05$ (SS/SG), $2.6\text{E-}05$ (SS/DG), $7.6\text{E-}05$ (SB/SG), and $2.5\text{E-}05$ (SB/DG). The medium-specific total hazards are as follows: SS ($1.6\text{E-}05$) -- driven by arsenic and BaPE; SB ($1.5\text{E-}05$) -- driven by arsenic and BaPE; SG ($6.1\text{E-}05$) -- driven by arsenic; and DG ($1.0\text{E-}05$) -- driven by arsenic.

Future Construction Workers

Construction workers were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to subsurface soil and shallow groundwater (construction workers would never encounter deep groundwater due to limits on the depth of any excavation).

Total hazard (1.1) slightly exceeds 1. The medium-specific hazards are as follows: SB (0.91) -- insignificant and SG (0.20) -- insignificant.

Total risk ($5.7\text{E-}07$) is less than $1\text{E-}06$ and considered insignificant.

Future Utility Workers

Utility workers were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to subsurface soil and shallow groundwater (utility workers would never encounter deep groundwater due to limits on the depth of any excavation).

Total hazard (0.086) is less than 1 and considered insignificant. Total risk (4.4E-06) is at the low end of EPA's target risk range and is driven by potential exposure to arsenic (3.0E-06) in subsurface soil.

BWC-N

BWC-N represents sampling locations along the northern and western boundaries of the BWC site. EPA was unable to access the adjacent farmland north and west of the BWC site. Because of their location at the boundaries of the BWC site, the sample locations within the BWC-N exposure area provide a conservative estimation of farmland north and west of the BWC site that may have become contaminated from the transport of site contaminants off-site through erosion, overland flow, and fugitive dust generation. The only receptor evaluated for this exposure area is the adult farmer under current (surface soil) and future (subsurface soil) conditions. Risks and hazards for the adult farmer are summarized in Table L-2-10 (see Appendix L) and discussed below.

Current and Future Adult Farmer

Adult farmers were evaluated under both current and future land use conditions. Total hazards and risks were evaluated for potential exposure to surface soil (current conditions) and subsurface soil (future conditions). Total hazards are less than 1 and considered insignificant under both current (0.031 [SS]) and future (0.36 [SB]) conditions. Total risks are at the low end of EPA's target risk range under both current (1.8E-06 [SS]) and future (1.7E-06 [SB]) conditions. Risks are driven by potential exposure to arsenic. (Note: these risks are very similar to potential exposure to background concentrations of arsenic in soil).

BWC-BKG

BWC-BKG represents soil and groundwater unimpacted by site activities. As described in Section 1.6.2, background soil samples (surface soil only) were collected from the Union Tank Car site, located south, across Holland Road, from the BWC Site. A series of five shallow groundwater wells (BWC-TW-25, BWC-TW-28, BWC-TW-54, BWC-TW-55, and BWC-MW2-S) located along the northern border of the BWC site and judged to be unimpacted by site activities were selected as representative of background groundwater conditions (see Figure L-1-6). Risks and hazards for each of the receptors evaluated for this exposure area are summarized in Table L-2-11 (see Appendix L) and discussed below.

Current and Future Adolescent and Adult Trespassers

Adolescent and adult trespassers were evaluated only under current land use conditions. No significant hazards were identified for adolescent trespassers ($5.3\text{E-}03$) and adult trespassers ($5.3\text{E-}03$). Similarly, no significant risks were identified for adolescent trespassers ($3.4\text{E-}07$) and adult trespassers ($1.0\text{E-}06$; driven by arsenic).

Current and Future Adult Farmer

Adult farmers were evaluated under both current (surface soil) and future (subsurface soil) conditions. No significant hazards were identified under current ($5.9\text{E-}03$) and future ($5.9\text{E-}03$) conditions. Total risks were at the low end of EPA's target risk range under current ($1.1\text{E-}06$) and future ($1.1\text{E-}06$) conditions. Risks are driven by potential exposure to arsenic.

Future Residents

Residents were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to surface and subsurface soil (assuming homes could be built using slab-on-grade construction [surface soil] or with basements, requiring excavation [subsurface]) and shallow and deep groundwater (allowing for variable depth of future groundwater well construction).

Total hazards exceed 1 under all soil and groundwater combinations: 4.8 (SS/SG) and 4.8 (SB/SG). The medium-specific total hazards are as follows: SS (1.5) – driven by arsenic; SB (1.5) – driven by arsenic; and SG (3.3) – driven by arsenic.

Total risks exceed $1\text{E-}04$, the upper end of EPA's target risk range, for all soil and groundwater combinations: $3.3\text{E-}04$ (SS/SG) and $3.3\text{E-}04$ (SB/SG). The medium-specific total risks are as follows: SS ($1.2\text{E-}04$) – driven by arsenic; SB ($1.2\text{E-}04$) – driven by arsenic; and SG ($2.1\text{E-}04$) – driven by arsenic.

Future Child Recreationalists

Child recreationalists were evaluated only under future land use conditions and assumed potential exposure to surface soil (no intrusive activity) and subsurface soil (assuming intrusive activity in developing the recreational space). Total hazards are less than 1 and considered insignificant for both surface ($4.6\text{E-}02$) and subsurface ($4.6\text{E-}02$) soil.

Total risks slightly exceed $1\text{E-}06$ assuming potential exposure to surface soil ($1.8\text{E-}06$) and subsurface soil ($1.8\text{E-}06$).

Future Adolescent Recreationalists

Adolescent recreationalists were evaluated only under future land use conditions and assumed potential exposure to surface soil (no intrusive activity) and subsurface soil (assuming intrusive activity in

developing the recreational space). Total hazards are less than 1 and considered insignificant for both surface ($5.3\text{E-}03$) and subsurface ($5.3\text{E-}03$) soil.

Total risks are less than $1\text{E-}06$ and considered insignificant assuming potential exposure to surface soil ($3.4\text{E-}07$) and subsurface soil ($3.4\text{E-}07$).

Future Adult Recreationalists

Adult recreationalists were evaluated only under future land use conditions and assumed potential exposure to surface soil (no intrusive activity) and subsurface soil (assuming intrusive activity in developing the recreational space). Total hazards are less than 1 and considered insignificant for both surface ($5.3\text{E-}03$) and subsurface ($5.3\text{E-}03$) soil.

Total risks equal $1\text{E-}06$ assuming potential exposure to surface soil ($1.0\text{E-}06$) and subsurface soil ($1.0\text{E-}06$); risks driven by arsenic.

Future Industrial/Commercial Workers

Industrial/commercial workers were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to surface and subsurface soil and shallow and deep groundwater (as described above for residents).

Total hazards are less than 1 and considered insignificant under all soil and groundwater combinations evaluated: 0.55 (SS/SG) and 0.55 (SB/SG).

Total risks are within EPA's target risk range, under all soil and groundwater combinations: $5.9\text{E-}05$ (SS/SG) and $5.9\text{E-}05$ (SB/SG). The medium-specific total hazards are as follows: SS ($9.5\text{E-}06$) – driven by arsenic; SB ($9.5\text{E-}05$) – driven by arsenic; and SG ($4.9\text{E-}05$) – driven by arsenic.

Future Construction Workers

Construction workers were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to subsurface soil and shallow groundwater (construction workers would never encounter deep groundwater due to limits on the depth of any excavation).

Total hazard (0.20) is less than 1 and considered insignificant. Total risk ($3.0\text{E-}07$) is less than $1\text{E-}06$ and considered insignificant.

Future Utility Workers

Utility workers were evaluated only under future land use conditions. Total hazards and risks were evaluated for potential exposure to subsurface soil and shallow groundwater (utility workers would never encounter deep groundwater due to limits on the depth of any excavation).

Total hazard (0.016) is less than 1 and considered insignificant. Total risk (2.3E-06) is at the low end of EPA's target risk range and is driven by potential exposure to arsenic (2.3E-06) in subsurface soil.

Overall BWC HHRA Conclusions

The following conclusions were drawn for the BWC HHRA:

- Total risks exceed 1E-04, the upper end of EPA's target risk range for future residents, child recreationalists (surface soil only), future industrial/commercial workers, future construction workers, and future utility workers at BWC-E and for future residents (BWC-W).
- Total risks and hazards are about 1 to 2 orders of magnitude higher at BWC-E as compared to BWC-W.
- Soil risks are driven by potential exposure to BaPE and to a less extent arsenic.
- Groundwater risks for residents and industrial/commercial workers are driven by potential exposure to BaPE, and to a lesser extent, arsenic and 1-methylnaphthalene. It should be noted that at BWC-E, the following organics also contributed to groundwater risks: 1,1'-biphenyl, ethyl benzene, and benzene.
- Groundwater risks for construction workers and utility workers at BWC-E are driven by potential exposure to naphthalene (via inhalation of vapors in a trench), and to a lesser extent, the same groundwater COPCs described in the preceding bullet. Groundwater risks for these same receptors are negligible at BWC-W.
- Soil hazards exceed 1 only for residents (BWC-E and BWC-W). These hazards are driven by various metals including arsenic, cadmium, cobalt, copper, iron, and manganese, as well as several PAHs (BWC-E only).
- Total risks and hazards for BWC-N (adult farmer) are similar to those calculated for the same receptor at BWC-BKG.

Finally, total risks and hazards calculated under CTE conditions are about 3 to 10 times lower than those calculated under

7.0 LSR AND BWC ECOLOGICAL RISK ASSESSMENT

The following sections discuss the screening level ecological risk assessment (SLERA) objectives, exposure areas, approach, results, and a summary of overall conclusions for the LSR and BWC sites. Additional information can be found in Appendix L.

7.1 OBJECTIVE

The purpose of an ecological risk assessment (ERA) is to evaluate the likelihood that adverse ecological effects are occurring or may potentially occur as a result of the site-specific constituent concentrations in environmental media. This SLERA conservatively characterizes ecological risks potentially associated with the LSR and BWC sites under conditions at the time of the RI (i.e., unremediated conditions).

This ERA was performed in accordance with the EPA Ecological Risk Assessment Guidance for Superfund (ERAGS; EPA 1997a) eight-step process and consistent with Ohio EPA Ecological Risk Assessment guidance (Ohio EPA 2008).

7.1.1 Exposure Areas

The primary objective of the first step in the SLERA is to identify exposure areas. The following sections discuss the LSR and BWC Exposure Areas. The exposure areas defined for RI purposes were redefined for the risk assessments.

7.1.1.1 LSR Exposure Areas

In October 2010, SulTRAC conducted a habitat evaluation of the LSR site to gather data necessary to identify potential ecological receptors and develop a CSM for the ERA to be conducted for the LSR. Habitat characterization activities focused on the riparian habitat associated with the river. The LSR site was divided into five exposure areas - (1) LSR-UP1 (Upstream); (2) LSR-DWN1 (Downstream 1)[previously remediated area] (3) LSR-DWN2 (Downstream 2) [downstream of the remediated area and visual sediment contamination]; (4) LSR-DWN3 (Downstream 3) [downstream of the remediated area to the confluence with the Scioto River and no visual sediment contamination]; and (5) LSR-DWN4 (Downstream 4) [Columbia and South Rockswale Ditches]. The LSR site was subdivided into these exposure areas, primarily on the past remediation activities and to establish an upstream reference location. The habitat type, general cover, and adjacent land use is generally consistent over the entire length of the LSR site, with the exception of the upstream area, which has portions that are considered a

high quality stream (Ohio EPA 2008b). (Note: these areas also correspond to the human health exposure areas.)

7.1.1.2 BWC Exposure Areas

In October 2010, SulTRAC conducted a habitat evaluation of the BWC site to gather data necessary to identify potential ecological receptors and develop a CSM for the ERA to be conducted for BWC.

SulTRAC identified the following three different habitat types with regards to the SLERA - (1) the original plant site which is moderately disturbed but contains grasses and limited shrubs and small trees, (2) the former product storage area with secondary growth, which includes woodland, shrubs, and herbs, and (3) the adjacent agricultural land, although currently cultivated could support ecological population over time.

7.1.2 SLERA Approach

The primary objective of second step in the SLERA is to identify chemicals of potential ecological concern (COPEC) and provide a conservative evaluation of the potential for adverse ecological effects related to constituent concentrations in environmental media. This step combines the ecological screening values (ESV) with exposure information to yield an estimate of potential ecological risks at the Site. The identification of the ESVs, exposure estimates, and risk calculations are summarized below.

7.1.2.1 LSR Approach

Using information on the habitats present and known areas of contamination, an ecological CSM was prepared which identifies likely categories of receptors with anticipated complete exposure pathways, and identifies assessment endpoints for the ecological evaluation. Potential exposure points, exposure routes, and ecological receptors at the Site are discussed in the following subsections for the LSR. The CSM is diagrammatically presented in Figure RA-3-1 (see Appendix L).

Sediment is the major contaminated medium identified for aquatic habitat of the LSR, and surface water is the secondary contaminated media of concern. Impacts to sediment and surface water are primarily the result of historical wood treating with creosote operations at the BWC as described in earlier sections. For the aquatic portions of LSR, the SLERA focused on benthic, aquatic (fish), and upper-trophic level, semi-aquatic avian and mammalian receptors.

The specific assessment endpoints evaluated in the LSR SLERA are:

- Ensure adequate protection of the benthic and aquatic communities in LSR by protecting them from the deleterious effects of acute and chronic exposures to site-related constituents present in the river.
- Ensure adequate protection of the aquatic-dependent mammalian and avian populations along the shoreline of the LSR by protecting them from the deleterious effects of acute and chronic exposures to site-related constituents due to biotic uptake of constituents in sediment and surface water.
- Ensure adequate protection of threatened and endangered species (including candidate species) and species of special concern and their habitats by protecting them from the deleterious effects of acute and chronic exposures to site-related constituents.

The final component of is the screening level ecological effects evaluation that identifies threshold exposure concentrations for constituents in environmental media below which adverse effects are not expected to occur. These are highly conservative constituent concentrations which are unlikely to result in adverse ecological effects even to the most sensitive ecological receptors. In Step 2, these values are used as bases to evaluate whether there may be a potential for adverse ecological effects as a result of exposure to constituents in environmental media. Several potential sources were reviewed to identify appropriate ESV for the SLERA.

EPCs for the SLERA are maximum detected concentrations of constituents in exposure media. Thus, the EPCs represent the maximum exposures expected at a given exposure area. The comparison resulted in an hazard quotient (HQ) such that:

$$HQ = \frac{EPC}{ESV}$$

The EPA HQ threshold value of 1 was used to identify COPECs. Generally, the greater the HQ, the greater the likelihood an effect will occur. Although probabilities cannot be specified based on a point-estimate approach, an HQ of approximately 1 is generally regarded as indicating a low probability of adverse ecological effects. When a constituent has an HQ greater than 1, it is present at levels above its threshold concentration; however, this does not imply that adverse effects will occur, only that the potential for adverse effects exists.

7.1.2.2 Expanded SLERA Approach

The expanded SLERA risk characterization process integrates information from the exposure and effects assessments to evaluate relationships among chemicals and adverse effects on organisms. This integration relies on site-specific chemical analytical data, selection of COPECs, site-specific

bioaccumulation information, food chain models (FCM), and available scientific literature. The expanded SLERA attempts to use as many site-specific assumptions as possible, sediment chemistry, fish and invertebrate concentrations to make the assessment reflect site conditions.

Sediment Chemistry

Two factors were evaluated to assess the potential toxicity associated with the sediments in the LSR. To assess potential impact of metals, the AVS, SEM and f_{oc} data from samples collected from the LSR were evaluated. Potential effects of metal-contaminated sediments can be predicted by evaluating the SEM, AVS, and f_{oc} concentrations (Di Toro and others 2005). DiToro and others (1990) showed that AVS binds with metals in the sediments in a sulfide complex; once bound, the metals are not bioavailable and toxicity is not exhibited. Moreover, f_{oc} will also combine with toxic metals and render them unavailable, thereby reducing their toxicity (DiToro and others 2005). The second factor was to evaluate the PAH concentrations taking into account the sediment's organic carbon content which will influence the bioavailability of these contaminants. SulTRAC followed the protocols outlined by EPA (EPA 2003). The objective of this analysis is to determine if the sum of the ESBTU for all PAH compounds in the sample tested exceeds 1. Exceedance of 1 indicates potential sediment toxicity due to the PAH compounds present.

Food Chain Model

To evaluate the potential risks to mammalian and avian receptors that use the LSR as food source, a FCM was used. The FCMs estimates the dose of site-related constituents to upper trophic level receptors based on the ingestion of COPECs in sediment, surface water, and prey items. An HQ approach was used as the measurement endpoint (to evaluate potential impacts from COPECs on the survival and reproduction of mammalian and avian populations that forage/feed in the LSR).

Assessment Endpoints. There were no changes in the general assessment endpoints for the higher trophic level receptors in the LSR as described earlier. The assessment endpoints noted above were further refined to focus on specific portions of the terrestrial ecosystem at BWC. The endpoints focus on specific exposure pathways for a variety of higher trophic level receptors and include the following:

- Protection of piscivore avian community
- Protection of piscivore mammalian community

Measurement endpoints. Measurement endpoints define the measures that will be employed to quantify and predict attainment of assessment endpoints. Measurement endpoints are measures of adverse effects on ecological receptors in response to a stressor. Measures of ecosystem characteristics are measures that influence behaviors and locations of ecological receptors, distribution of stressors, and life-history characteristics of ecological receptors that may affect exposure or response to the stressor (EPA 1998). The measurement endpoints selected for each assessment are presented as follows:

Assessment Endpoint	Receptors	Representative Species	Measurement Attribute
Protection of the piscivorous mammalian community function and viability	Piscivorous Mammal	Mink	Food chain modeling and dose comparison with TRVs
Protection of the piscivorous avian community function and viability	Piscivorous Bird	Belted Kingfisher	Food chain modeling and dose comparison with TRVs

Potential exposure routes for upper trophic-level receptors include direct exposure to abiotic media (e.g., sediment) via ingestion, dermal contact, and inhalation, and dietary exposure to biotic media via the consumption of bioaccumulated/ bioconcentrated contaminants in food/prey items.

FCMs used results for surface sediment samples collected from 0 to 1 foot below sediment surface (bss) from each exposure area of the LSR to estimate doses to avian and mammalian receptors. The exposure point concentrations for sediment, fish tissue, and invertebrate tissue were calculated using ProUCL 4.1 (EPA 2007) and represent the 95 percent upper confidence level about the mean.

Low and high TRVs were developed to evaluate potential ecological effects from site COPECs. NOAEL and LOAEL TRVs were used as low and high benchmarks, respectively, to evaluate potential risks to upper trophic level receptors. The mammalian and avian TRVs are presented in Tables 3-5 and 3-6, respectively (see Appendix L).

COPEC doses were calculated for each receptor using average values for exposure parameters such as body weight and ingestion rate and soil EPCs. By calculating both a $HQ_{(dose/high\ TRV)}$ and $HQ_{(dose/low\ TRV)}$ for soil concentrations, a risk manager can more definitively assess risk to the typical individual in the overall population. The interpretation of each HQ is summarized as follows:

Hazard Quotient Interpretation (HQ = Dose/TRV)		
Less Than Low TRV	Between Low and High TRV	Greater than High TRV
HQ(dose/low TRV) < 1 indicates little or no risk to average receptor	Between HQ(dose/high TRV) < 1 and HQ(dose/low TRV) > 1 indicates potential for risk to average receptor. However, the magnitude of the potential risk is uncertain.	HQ(dose/high TRV) > 1 indicates potential significant risk to average receptor

7.1.3 BWC Approach

The focus of the ecological risk assessment for BWC is only soils within the three habitats identified: former main plant- disturbed with vegetation, former storage area disturbed with secondary growth, and the adjacent agricultural land. The exposure areas were redefined for the risk assessments. During the ecological habitat characterization, a variety of receptors were observed at BWC, and other receptors, although not observed directly, are likely present. These include plants, soil invertebrates, birds, and mammals in the terrestrial portions of BWC. Individual species are not evaluated in the SLERA; however, potentially complete exposure pathways are evaluated for general receptor categories.

As noted above, the SLERA for BWC focuses on soil as the main contaminated medium, and therefore the assessment endpoints focus on terrestrial receptors at BWC.

The specific assessment endpoints evaluated in the BWC SLE:

- Ensure adequate protection of terrestrial plant and soil invertebrate communities, including native plant communities.
- Ensure adequate protection of mammalian and avian populations.
- Ensure adequate protection of threatened and endangered species (including candidate species) and species of special concern and their habitats.

The BWC SLERA dataset includes analytical data obtained during the Phase I and II RI activities (SulTRAC 2012). The soil samples were analyzed for metals, VOCs, SVOCs including PAHs, pesticides, and cyanide. The assessment focused on the most biologically active portion of the surface soils—from 0 to 2 feet bgs.

Maximum concentrations (conservative estimate of EPCs) of constituents detected in each ecological exposure medium and exposure area were compared with the conservative ESVs identified in Step 1. The comparison resulted in an HQ such that:

$$HQ = \frac{EPC}{ESV}$$

The EPA HQ threshold value of 1 was used to identify COPECs. Generally, the greater the HQ, the greater the likelihood an effect will occur. Although probabilities cannot be specified based on a point-estimate approach, an HQ of approximately 1 is generally regarded as indicating a low probability of adverse ecological effects. When a constituent has an HQ greater than 1, it is present at levels above its threshold concentration; however, this does not imply that adverse effects will occur, only that the potential for adverse effects exists.

7.1.3.1 Expanded SLERA Approach

The expanded SLERA risk characterization process integrates information from the exposure and effects assessments to evaluate relationships among chemicals and adverse effects on organisms. This integration relies on site-specific chemical analytical data, selection of COPECs, refined evaluation of soil chemistry for plant and invertebrate receptors, and FCMs for mammalian and avian receptors. The expanded SLERA attempts to use as many site-specific assumptions as possible, however, for the BWC, this was limited to revised EPCs to reflect a reasonable maximum concentration, and fish and invertebrate concentrations for limited number of receptors.

Expanded Soil Screening and Food Chain Model

As noted above, focus at BWC is on the upland terrestrial ecosystem and its components.

- ***Plants and Soil Invertebrates.*** The primary exposure pathway for both terrestrial plants and soil invertebrates is direct contact with contaminated soils.
- ***Birds and Mammals.*** As noted in the CSM, birds and mammals may be exposed via ingestion of surface water, soils, and dietary items. In the SLERA, these pathways were evaluated only by comparison of soil concentrations to screening values developed to assess a variety of receptors and pathways. In the expanded SLERA, a variety of avian and mammalian receptors were quantitatively evaluated. This evaluation also incorporated site-specific information obtained for soil contaminant levels and limited information on prey tissue data.

Assessment Endpoints. There were no changes in the assessment endpoints for the upland portion of BWC as described earlier. The assessment endpoints noted above were further refined to focus on

specific portions of the terrestrial ecosystem at BWC. The endpoints focus on specific exposure pathways for a variety of terrestrial receptors and include the following:

- Protection of the terrestrial plant community function and viability
- Protection of the soil invertebrate community function and viability
- Protection of the herbivorous mammalian community function and viability
- Protection of the invertivorous mammalian community function and viability
- Protection of the omnivorous mammalian community function and viability
- Protection of the carnivorous mammalian community function and viability
- Protection of the herbivorous avian community function and viability
- Protection of the invertivorous avian community function and viability
- Protection of the omnivorous avian community function and viability
- Protection of the carnivorous avian community function and viability.

Measurement Endpoints. Measurement endpoints are measures of adverse effects on ecological receptors in response to a stressor. Measures of ecosystem characteristics are measures that influence behaviors and locations of ecological receptors, distribution of stressors, and life-history characteristics of ecological receptors that may affect exposure or response to the stressor (EPA 1998). The measurement endpoints selected for each assessment are presented as follows:

Assessment Endpoint	Receptors	Representative Species	Measurement Attribute
Protection of the terrestrial plant community function and viability	Terrestrial Plants	No specific species	Comparisons of 95 percent UCL soil concentrations to ESVs for protection of plants.
Protection of the soil invertebrate community function and viability	Soil Invertebrates	Earthworm	Comparisons of 95 percent UCL soil concentrations to Screening values for protection of invertebrates
Protection of the herbivorous mammalian community function and viability	Herbivorous Mammal	Meadow vole	Food chain modeling and dose comparison with TRVs
Protection of the omnivorous mammalian community function and viability	Omnivorous Mammal	Deer mouse	Food chain modeling and dose comparison with TRVs
Protection of the omnivorous mammalian community function and viability	Omnivorous Mammal	Raccoon	Food chain modeling and dose comparison with TRVs
Protection of the carnivorous mammalian community function and viability	Carnivorous Mammal	Red fox	Food chain modeling and dose comparison with TRVs

Assessment Endpoint	Receptors	Representative Species	Measurement Attribute
Protection of the herbivorous avian community function and viability	Herbivorous Bird	Bobwhite	Food chain modeling and dose comparison with TRVs
Protection of the omnivorous avian community function and viability	Omnivorous Bird	American robin	Food chain modeling and dose comparison with TRVs
Protection of the carnivorous avian community function and viability	Carnivorous Bird	American kestrel	Food chain modeling and dose comparison with TRVs

The measurement endpoints are focused on a number of guilds within several major groups of receptors—plants, soil invertebrates, mammals, and birds. A similar approach is followed within each of these groups. The following is a brief discussion of the measurement endpoints used for this step.

- Plants – comparison of soil and sediment COPEC concentrations to ecotoxicity screening values:** Concentrations of COPECs in soil were compared with screening values for plants following the hierarchy identified in Section 3.1.3.1. The screening values are presented in Appendix RA-9, Table RA-9-1 (see Appendix L). HQs were developed by dividing the 95 percent UCL by the plant screening value. Potential risk was indicated where concentration of a COPEC in site soil exceeded the plant screening value.
- Terrestrial macroinvertebrates – comparison of soil COPEC concentrations to ecotoxicity benchmarks:** Concentrations of COPECs in soil were compared to soil invertebrate screening values following the hierarchy identified in Section 3.1.3.1. The screening values are presented in Appendix RA-9, Table RA-9-2 (see Appendix L). HQs were developed by dividing the 95 percent UCL by the invertebrate screening value. Potential risk was indicated where concentration of a COPEC in site soil exceeded the screening value.
- Mammalian receptors – reproductive or physiological effects to meadow vole, deer mouse, raccoon, and red fox:** The meadow vole was used as a surrogate for herbivorous mammal populations, the deer mouse and raccoon for omnivorous mammal populations, and the red fox for carnivorous mammal populations at BWC. A conservative daily dose was calculated based on a COPEC's EPCs and average natural history parameters for these mammals. HQs were developed by dividing the daily dose for each COPEC by the appropriate literature-derived TRV.
- Avian consumers – reproductive or physiological effects to the northern bobwhite, American robin, and American kestrel:** The northern bobwhite was used as a surrogate to represent herbivorous bird populations, the American robin to represent omnivorous bird populations, and the American kestrel to represent carnivorous bird populations at BWC. A conservative daily dose was calculated based on a COPEC's EPCs and average natural history parameters. HQs were developed by dividing the estimated daily dose for each COPEC by the appropriate literature-derived TRV.

The site investigation of BWC was conducted by SulTRAC in multiple field events from April 2011 to February 2012. The site investigation included sampling of soil. Summary tables for the contamination

identified in each habitat are presented in Tables RA-S3-1 through S3-5 (see Appendix L). Each table includes the number of samples analyzed for each COPEC, the number of detections, the maximum detected concentration, and the mean and the 95 percent UCL calculated following the procedures outlined in ProUCL 4.1 (EPA 2009l).

Estimated COPEC doses were calculated for each receptor using average values for exposure parameters such as body weight and ingestion rates and EPCs. These doses were then compared with high and low TRVs to estimate the potential for adverse biological effects on the receptor. The risk to each representative species was characterized using a HQ approach based on this comparison (see the LSR expanded SLERA above for discussion of the HQ approach).

7.2 RESULTS

This section presented the SLERA results used to determine whether an expanded SLERA was necessary for a particular exposure area.

7.2.1 LSR Sediment Results

The following section presents the sediment results of the SLERA pertaining to LSR.

7.2.1.1 LSR-DWN1 – Downstream 1

The SLERA results for the Downstream Area 1, where sediment remediation has occurred, identified 26 COPECs with respective HQs greater than 1 based on maximum concentrations. Of the major groups of contaminants identified in the soils in the area, metals and PAHs had the highest HQs. The metals with the highest HQs were silver (18), antimony (12), and beryllium (8.4). The organic constituents with highest HQs in this habitat included fluorene (48), anthracene (42), pyrene (36), phenanthrene (35), benzo(a)anthracene (25), chrysene (21), and fluoranthene (21). Sediments in this area pose a potentially significant risk to ecological receptors, and metals and PAHs are the major risk drivers. Based on the above considerations, an expanded SLERA was conducted for the area that utilized limited site-specific data to further evaluate potential ecological exposure to COPECs in the aquatic habitat of the LSR.

7.2.1.2 LSR-DWN2 – Downstream 2

The SLERA results for the Downstream Area 2, downstream of the sediment remediation and visible contamination is present, identified 33 COPECs with respective HQs greater than 1 based on maximum concentrations. Of the major groups of contaminants identified in the soils in the area, metals and PAHs had the highest HQs. The metals with the highest HQs were silver (81), antimony (16), mercury (7) and beryllium (5). The organic constituents with highest HQs in this habitat included acenaphthalene

(23,800), anthracene (5,240), phenanthrene (2,940), chrysene (1,810), fluorene (1,810), pyrene (1,590), benzo(a)anthracene (1,480), chrysene (21), and fluoranthene (21). Sediments in this area pose a potentially significant risk to ecological receptors, and PAHs are the major risk drivers. Based on the above considerations, an expanded SLERA was conducted for the area that utilized limited site-specific data to further evaluate potential ecological exposure to COPECs in the aquatic habitat of the LSR.

7.2.1.3 LSR-DWN3 – Downstream 3

The SLERA results for the Downstream Area 3, downstream of the sediment remediation to the confluence of the Scioto River and no visible contamination is present, identified 31 COPECs with respective HQs greater than 1 based on maximum concentrations. Of the major groups of contaminants identified in the soils in the area, metals and PAHs had the highest HQs. The metals with the highest HQs were silver (54) and antimony (10). The organic constituents with highest HQs in this habitat included atrazine (861), acenaphthalene (849), hexachlorobenzene (285), benzo(a)anthracene (120), chrysene (96), pyrene (92), fluoranthene (74) and benzo(a)pyrene (73). Sediments in this area pose a potentially significant risk to ecological receptors, and PAHs and pesticides are the major risk drivers. Based on the above considerations, an expanded SLERA was conducted for the area that utilized limited site-specific data to further evaluate potential ecological exposure to COPECs in the aquatic habitat of the LSR.

7.2.1.4 LSR-DWN4 – Downstream 4

The SLERA results for the Downstream Area 4, tributaries to the LSR – Columbia and South Norwich Ditches, identified 26 COPECs with respective HQs greater than 1 based on maximum concentrations. Of the major groups of contaminants identified in the soils in the area, metals and PAHs had the highest HQs. The metals with the highest HQs were silver (58) and antimony (8). The organic constituents with highest HQs in this habitat included chrysene (45), bis(2-ethylhexyl)phthalate (45), benzo(a)anthracene (43), atrazine (35), acenaphthalene (27), pyrene (25), and fluoranthene (15). Sediments in this area pose a potentially significant risk to ecological receptors, and PAHs and pesticides are the major risk drivers. Based on the above considerations, an expanded SLERA was conducted for the area that utilized limited site-specific data to further evaluate potential ecological exposure to COPECs in the aquatic habitat of the LSR.

7.2.1.5 LSR-UP1 – Upstream 1

The SLERA results for the Upstream Area 1, the area considered the reference area, identified 13 COPECs with respective HQs greater than 1 based on maximum concentrations. Of the major groups of contaminants identified in the soils in the area, metals and PAHs had the highest HQs. The metals with the highest HQs were silver (93) and antimony (13); these values are consistent with the other stations indicating that these metals concentrations are likely background levels or their source is clearly not the BWC site. There were several organic constituents, PAHs, with HQs just above 1. The PAHs with the highest HQs in this habitat included chrysene (45), bis(2-ethylhexyl)phthalate (45), benzo(a)anthracene (43), atrazine (35), acenaphthylene (27), pyrene (25), and fluoranthene (15). Sediments in this area pose a potentially significant risk to ecological receptors, and PAHs and pesticides are the major risk drivers. Based on the above considerations, an expanded SLERA was conducted for the area that utilized limited site-specific data to further evaluate potential ecological exposure to COPECs in the aquatic habitat of the LSR.

7.2.2 LSR Surface Water Results

The following section presents the surface water results of the SLERA pertaining to LSR.

7.2.2.1 LSR-DWN1 – Downstream 1

The SLERA results for the Downstream Area 1, where sediment remediation has occurred, identified 3 COPECs with respective HQs greater than 1 based on maximum concentrations. Of the major groups of contaminants identified in the surface waters in the area, metals and SVOCs had the highest HQs. The metals with the highest HQs were iron (4.4), and manganese (2.7). The only organic constituents with an HQ greater than 1 in this habitat was bis(2-ethylhexyl)phthalate (4.4). These results indicate a potential impact; however, these constituents are not believed to be associated with releases from the BWC site.

7.2.2.2 LSR-DWN2 – Downstream 2

The SLERA results for the Downstream Area 2, downstream of the sediment remediation and visible contamination is present, identified 2 COPECs with respective HQs greater than 1 based on maximum concentrations. Of the major groups of contaminants identified in the surface waters in the area, metals and SVOCs had the highest HQs. The only metal with an HQ greater than 1 was iron (1.2). The only organic constituents with an HQ greater than 1 in this habitat was bis(2-ethylhexyl)phthalate (3.8). These results indicate a potential impact; however, these constituents are not believed to be associated with releases from the BWC site.

7.2.2.3 LSR-DWN3 – Downstream 3

The SLERA results for the Downstream Area 3, downstream of the sediment remediation to the confluence of the Scioto River and no visible contamination is present, did not identify any COPECs with respective HQs greater than 1 based on maximum concentrations. Therefore, no risks to aquatic life from surface water were identified for this area.

7.2.2.4 LSR-DWN4 – Downstream 4

The SLERA results for the Downstream Area 4, tributaries to the LSR – Columbia and South Norwich Ditches, did not identify any COPECs with respective HQs greater than 1 based on maximum concentrations. Therefore, no risks to aquatic life from surface water were identified for this area.

7.2.2.5 LSR-UP1 – Upstream 1

The SLERA results for the Upstream Area 1, the area not impacted by releases from the BWC site and the reference area, did not identify any COPECs with respective HQs greater than 1 based on maximum concentrations. Therefore, no risks to aquatic life from surface water were identified for this area.

7.2.2.6 Expanded SLERA Results

Sediment Chemistry

Two factors were evaluated to assess the potential toxicity associated with the sediments in the LSR. To assess the potential impact of metals, the AVS, SEM, f_{oc} data from samples collected from the LSR were evaluated. Potential effects of metal-contaminated sediments can be predicted by evaluating the SEM, AVS, and f_{oc} concentrations (DiToro and others 2005). DiToro and others (1990) and DiToro and others (2005) showed that AVS and organic carbon binds with metals in the sediments in a sulfide complex and biotic ligand; once bound, the metals are not bioavailable and toxicity is not exhibited. The samples were collected from the areas with the highest levels of contamination – Downstream Area 2 and 3. The ratio of SEM-AVS and f_{oc} showed that metals are not likely to be bioavailable and would not be expected to express toxicity in the sediments.

The second factor was to evaluate the PAH concentrations taking into account the sediment's organic carbon content which will influence the bioavailability of these contaminants. SulTRAC followed the protocols outlined by EPA (EPA 2003). The objective of this analysis is to determine if the sum of the ESBTU for all PAH compounds in the sample tested exceeds 1. Exceedance of 1 indicates potential sediment toxicity due to the PAH compounds present. The results for the individual sample locations

showed ESBTU levels significantly above 1, especially in the Downstream Area 2, where the values ranged from 47 at SD-19 to 3 at SD-11. This indicates a potential for significant toxicity to benthic organisms in this area.

Food Chain Model

A FCM was used to assess the potential impacts to mammalian and avian receptors that may use the LSR as a food source. Site-specific information on fish and invertebrate tissue concentrations for specific sections of the LSR were used in the model, along with sediment concentrations to estimate potential doses to the receptors. Toxicity reference values were used to assess the potential doses and an HQ was determined – the HQ exceeded 1, this may indicate a potential unacceptable risk to the receptor. Two receptors were used in the FCM – mink and belted kingfisher – to represent the two likely guilds to be exposed, a piscivorous mammal and avian receptors. The FCM did not identify any portion of the LSR that may cause an unacceptable risk to these receptors.

7.2.3 BWC Results

This section presents the results of the SLERA and the expanded SLERA. Each of these is discussed below.

7.2.3.1 SLERA Results

This section presented the SLERA results for each of the exposure areas evaluated at the BWC site.

Former Main Plant Area (BWC-E)

The SLERA results for the Main Plant area, highly disturbed habitat, identified 36 COPECs with respective HQs greater than 1 based on maximum concentrations. Of the major groups of contaminants identified in the soils in the area, metals had the highest HQs. The metals with the highest HQs were iron (2,110), manganese (527), aluminum (434), lead (171), chromium (79), copper (57), and nickel (54). The organic constituents with highest HQs in this habitat included naphthalene (604), benzo(a)pyrene (169), chrysene (66), and benzo(a)anthracene (64). Clearly the soils in this area pose a potentially significant risk to ecological receptors, and metals and PAHs are the major risk drivers.

Former Product Storage Area (BWC-W)

The SLERA results for the former product storage area adjacent to the Main Plant, disturbed habitat with vegetation, identified 16 COPECs with respective HQs greater than 1 based on maximum concentrations. Of the major groups of contaminants identified in the soils in the area, metals had the highest HQs. The metals with the highest HQs were aluminum (668), iron (192), antimony (22), and copper (11). The

organic constituents with highest HQs in this habitat were just above 1 and are not anticipated to be a significant impact. The soils in this area pose a potentially risk to ecological receptors, and metals are the major risk drivers.

Adjacent Agricultural Land

The SLERA results for the adjacent agricultural land habitat identified 13 COPECs with respective HQs greater than 1 based on maximum concentrations. Of the major groups of contaminants identified in the soils in the area, metals had the highest HQs. The metals with the highest HQs were aluminum (420), iron (106), manganese (6), and vanadium (6). The organic constituents with highest HQs in this habitat included naphthalene (10), and benzo(a)pyrene (2). The soils in this area pose a potentially significant risk to ecological receptors, and metals are the major risk drivers.

7.2.3.2 Expanded SLERA Results

Former Main Plant Area (BWC-E)

The expanded SLERA identifies significant risks to all receptor communities. As can be seen in the listing below, metals and PAHs are the predominant risk drivers for this habitat. For the lower trophic levels, the major risk drivers are aluminum, chromium, lead, and a variety of PAHs. For mammalian receptors, the major common risk drivers are chromium, copper, and high molecular weight PAHs. For avian receptors, the most common risk drivers are lead, mercury, selenium, and zinc.

Receptor Community	Receptor	Major Risk Drivers
Plants	Plants	Aluminum, Chromium, Copper, Manganese, Nickel Vanadium
Soil Invertebrates	Earthworm	Chromium, Manganese, Mercury, Zinc, PAHs
Herbivorous Mammals	Meadow vole	Chromium, Copper, Mercury, High Molecular Weight PAHs
Omnivorous Mammals	Deer mouse	Chromium, Copper, Lead, Nickel, Thallium, Vanadium, High Molecular Weight PAHs
Omnivorous Mammals	Raccoon	None identified
Carnivorous Mammals	Red fox	None identified
Herbivorous Birds	Northern bobwhite	Copper, Nickel
Omnivorous Birds	American robin	Cadmium, Copper, Nickel, Zinc, Endrin ketone
Carnivorous Birds	American kestrel	Endrin ketone

Former Product Storage Area (BWC-W)

The expanded SLERA identifies limited risks to all receptor communities except raccoons, red foxes, and American kestrel. As can be seen in the listing below, metals are the predominant major risk drivers for this habitat. For the lower trophic levels, the major risk drivers are aluminum, chromium, and vanadium. For the mammalian and avian receptors, the major common risk driver is vanadium. There were limited risks identified with the high TRV, which represent a LOAEL, this indicates that there will be limited toxicity expected to be expressed.

Receptor Community	Receptor	Major Risk Drivers
Plants	Plants	Aluminum, Chromium, Vanadium
Soil Invertebrates	Earthworm	Vanadium
Herbivorous Mammals	Meadow vole	Vanadium
Omnivorous Mammals	Deer mouse	Thallium, Vanadium
Omnivorous Mammals	Raccoon	None identified
Carnivorous Mammals	Red fox	None identified
Herbivorous Birds	Northern bobwhite	Copper
Omnivorous Birds	American robin	Copper
Carnivorous Birds	American kestrel	None identified

Adjacent Agricultural Land

The expanded SLERA identifies limited risks to all receptor communities except raccoons, red foxes, northern bobwhites, American robins, and American kestrels. As indicated in the listing below, metals are the only major risk drivers within this habitat. For the lower trophic levels, the major risk drivers are aluminum, chromium, and vanadium. For mammalian receptors, the major common risk drivers are thallium and vanadium. There were limited risks identified with the high TRV, which represent a LOAEL, this indicates that there will be limited toxicity expected to be expressed.

Receptor Community	Receptor	Major Risk Drivers
Plants	Plants	Aluminum, Chromium, Vanadium
Soil Invertebrates	Earthworm	Chromium
Herbivorous Mammals	Meadow vole	Vanadium
Omnivorous Mammals	Deer mouse	Thallium, Vanadium
Omnivorous Mammals	Raccoon	None identified
Carnivorous Mammals	Red fox	None identified
Herbivorous Birds	Northern bobwhite	None identified
Omnivorous Birds	American robin	None identified
Carnivorous Birds	American kestrel	None identified

7.3 SLERA CONCLUSIONS

This section presents the conclusions of the SLERA and expanded SLERA for the LSR and BWC sites. Conclusions for each site are discussed below.

7.3.1 LSR Conclusions

The ERA for the LSR Site was performed in accordance with the EPA ERAGS (1997a) eight-step process. Steps 1 and 2 (i.e., the SLERA) were presented in Section 3.0 of this document. The SLERA conclusions are presented below:

- Concentrations of several constituents, primarily PAHs and metals in sediments in the LSR metals exceed SLERA ESVs for benthic aquatic wildlife receptors. The further evaluation of the sediment data, noted that the metals are not likely to exhibit toxicity in the sediment, but it is likely the PAHs may have a major impact on the benthic community, specifically in Downstream Area 2.
- Concentrations of several constituents, primarily metals and PAHs, in sediments were shown to have a limited impact on mammalian and avian receptors in a limited area. Based on this information, there does not appear to be a rationale for any further investigation of this exposure pathway and these ecological receptors. Therefore, further evaluation in a Baseline Ecological Risk Assessment (BERA) is not warranted.
- Concentrations of several constituents, primarily PAHs, in the sediment and surface water of the LVR exceed SLERA ESVs for benthic and aquatic receptors. This is consistent with the biological assessment studies conducted by Ohio EPA (2008a and 2012). The LSR is the most ecologically valuable habitat associated with the site. Therefore, further evaluation in a BERA is recommended for this riverine/riparian habitat to verify the extent of the sediments toxicity and potential remedial options.

7.3.2 BWC Conclusions

For the purposes of the ERA, the BWC was subdivided into ecological exposure areas primarily on the basis of areas of known habitat, past land use and potential future use. The primary objective of the SLERA was to evaluate, for each ecological exposure area, whether a more detailed ecological risk assessment (i.e., a BERA) is warranted.

The results of the BWC SLERA support the following conclusions and recommendations:

- The results from the SLERA for the BWC clearly show that portions of BWC have elevated concentrations of metals, pesticides, and PAHs that may pose potentially unacceptable risks to ecological receptors. The former main plant area is the portion that showed the highest risk. However, this property is of limited ecological significance, because it is an isolated habitat that is surrounded by agricultural fields on three sides and an industrial operation to the other side. Based on this information, a BERA is not recommended for BWC site.

8.0 CONCLUSIONS AND RECOMMENDATIONS

This section discusses conclusions of the RI and recommendations for further activities based on the conclusions. Conclusions and recommendations for LSR and BWC are discussed separately below.

8.1 LSR CONCLUSIONS

The following conclusions pertain to the LSR investigation:

- The LSR is a low-velocity, high-turbidity river that ranges between 30 and 45 feet wide and 6 inches to more than 5 feet deep in pooled areas
- Based on the investigation, sediment thickness within the LSR ranged from 2- to 84-inches thick. Sediment thickness within the connecting waterways ranged from 4- to 8-inches thick
- Water levels measured at each staff gauge and each corresponding cluster of temporary monitoring wells over a 3-week period indicates that the relationship between the groundwater and the LSR appears to vary based on location. At Keener Pike and Holland Road, the LSR appears to be losing, while at State Route 95 and State Route 739, the LSR appears to be gaining. Seasonal patterns influenced by precipitation events could result in periodic changes in the relationship between surface water and groundwater elevations.
- Ecological assessments of the LSR performed by Ohio EPA (Ohio EPA 1988 and 1994) have identified the LSR as not attaining aquatic life status based on biocriteria for the Eastern Corn Belt Plains ecoregion of Ohio
- Several state endangered species, which include plants, reptiles, birds, and freshwater mussels, inhabit the LSR
- For investigation purposes, the LSR was divided into five exposure areas including LSR-UP1 (the portions of the LSR and NRD upgradient of the previous removal action), LSR-DWN1 (the portions of the LSR and NRD addressed during the previous removal action), LSR-DWN2 (the portion of the LSR where visual contamination was identified during previous investigations), LSR-DWN3 (the portion of the LSR down to the confluence with the Scioto River where no visual contamination was observed during previous investigations), and LSR-DWN4 (the ditches and waterways adjacent to LSR, including Rockswale and Columbia Ditches)
- For purposes of characterizing the nature and extent of contamination in the LSR, the RI is considered to be complete
- Visual impacts (product in sediment or sheen on surface water when sediment was disturbed) were observed primarily in exposure area DWN-2 and to a lesser extent in exposure area DWN-3
- Inorganics and SVOCs were detected above one or more screening levels in sediment samples from all exposure areas investigated with the highest concentrations detected in exposure areas LSR-DWN2 and LSR-DWN3
- Inorganics and SVOCs were detected above one or more screening levels in surface water samples from all exposure areas investigated with the highest concentrations detected in exposure areas LSR-DWN2 and LSR-DWN3
- Inorganics and SVOCs were detected above one or more screening levels in low-lying surface soil samples from all exposure areas investigated with the highest concentrations detected in exposure areas LSR-DWN2 and LSR-DWN3

- Inorganics and SVOCs were detected above one or more screening level in invertebrate samples from all exposure areas investigated with the highest concentrations detected in exposure areas LSR-DWN2 and LSR-DWN3.
- Inorganics and SVOCs were detected above one or more screening level in fish tissue samples from all exposure areas investigated with the highest concentrations detected in exposure areas LSR-DWN2 and LSR-DWN3.
- Contamination in LSR river sediment does not appear to be leaching to and impacting shallow groundwater adjacent to the river
- TOC results from samples collected during the RI indicate that TOC values range from 2.12 to 19.20. These data are used in the risk assessment to adjust the screening levels for organic constituents in sediments since toxicity is based on an equilibrium partitioning between sediment particles and interstitial water
- The calculated SEM/AVS ratios ranged from 0.040 to 0.89 indicating that the inorganic compounds present in the sediment have limited bioavailability
- The presence of COIs within the previous removal action could be attributed to residual contamination above RI screening levels, redeposition from upstream areas, or runoff from roads and higher land into the LSR
- Total hazards are less than 1 and considered insignificant for all receptors with one exception; the total hazard for the child fish consumer is 1.3 (driven by potential exposure to thallium).
- Total risks are less than 1E-06 and considered insignificant or at the low end of EPA's acceptable risk range (less than 1E-05) for the adult farmer and adult utility worker.
- Total risks exceed 1E-04 (the upper end of EPA's acceptable risk range) for all recreational receptors in LSR-DWN2 and adult mussel consumers in LSR-ALL. All other risks are within EPA's acceptable risk range.
- Risks are driven primarily by potential exposure to BaPE (and individual potentially carcinogenic PAHs) in sediment. The primary exception are risks associated with potential exposure to indeno(1,2,3-cd)pyrene in surface water in LSR-DWN3. Risks associated with potential exposure to soil at LSR-DWN2 and -DWN3 are about one order of magnitude lower than the risks associated with potential exposure to sediment in the same areas.
- Total risks in the in-stream segments from highest to lowest are as follows:
 - LSR-DWN2
 - LSR-DWN3
 - LSR-DWN1 and LSR-DWN4
 - LSR-UP1
- Primary uncertainties relate to (1) the representativeness of the indeno(1,2,3-cd)pyrene detected in surface water at LSR-DWN3 and (2) the assumptions regarding fish and mussel consumption from LSR-ALL – do individuals regularly fish the LSR and are sufficient mussels present to support the assumed mussel consumption.
- Finally, the risks and hazards calculated under CTE conditions are about 2 to 12 times lower than those calculated under RME conditions depending on the receptor considered.
- Concentrations of several constituents, primarily PAHs and metals in sediments in the LSR metals exceed SLERA ESVs for benthic receptors. The further evaluation of the sediment data,

noted that the metals are not likely to exhibit toxicity in the sediment, but it is likely the PAHs may have a major impact on the benthic community, specifically in Downstream Area 2.

- Constituent concentrations in surface water did not show a significant impact to aquatic receptors in the LSR.
- Concentrations of several constituents, primarily metals and PAHs, in sediments were shown to have a limited impact on mammalian and avian receptors in a limited area. Based on this information, there does not appear to be a rationale for any further investigation of this exposure pathway and these ecological receptors. Therefore, further evaluation in a BERA is not warranted.
- Concentrations of several constituents, primarily PAHs, in the sediment and surface water of the LVR exceed SLERA ESVs for benthic and aquatic receptors. Further evaluation of sediment chemistry confirmed PAHs probable role in the potential toxicity. The LSR is the most ecologically valuable habitat associated with the site. Therefore, further evaluation in a BERA is recommended for this riverine/riparian habitat to verify the extent of the sediments toxicity and potential remedial options.

8.2 LSR RECOMMENDATIONS

The following recommendations pertain to LSR:

- Remedial action objectives (RAO) should be established for LSR sediment in exposure areas DWN-2 and DWN-3
- After RAOs are established, a FS should be conducted to evaluate potential remedial alternatives
- Any additional work (as part of the FS) needed to further refine the estimate of sediment to be addressed
- Further evaluation in a BERA is recommended for the riverine/riparian habitat to verify the extent of the sediments toxicity and potential remedial options.

8.3 BWC CONCLUSIONS

The following conclusions pertain to the BWC investigation:

- Unconsolidated materials encountered during drilling at the BWC site included several distinct types of materials including topsoil, slag, silty clay, and sand and gravel with a total thickness ranging from about 10 to 20 feet
- The depth to bedrock at the BWC site ranges from about 10 feet bgs to about 20 feet bgs. In general, the weathered bedrock surface is irregular and slopes downward from east to west.
- Groundwater present in the unconsolidated sand seams and in the weathered bedrock at the unconsolidated material/bedrock interface is referred to as shallow groundwater. Groundwater present in the fractured competent limestone bedrock is referred to as deep groundwater.
- Shallow and deep groundwater flow direction was confirmed to generally be in the westerly direction

- BWC was divided into two exposure areas including BWC-E (the Eastern portion of the BWC property containing the former processing area) and BWC-W (the Western portion of the BWC property containing the former drying area)
- Background soil concentrations were obtained from the Union Tank Car site (located south of Holland Road) and Marion County data obtained from USGS. Where two background inorganic concentrations existed, the concentration from Union Tank Car was used based on its proximity to the BWC site.
- One existing shallow permanent monitoring well (MW-2S) and four additional shallow temporary monitoring wells (BWC-TW25, BWC-TW28, BWC-TW54, and BWC-TW55) were installed along the northern (upgradient) boundary of the BWC site to provide upgradient water quality information for comparison purposes.
- VOCs were not detected in soil above screening levels in either exposure area
- SVOCs were detected in soil above one or more screening level in both exposure areas with the highest concentrations generally located in exposure area BWC-E near the former bioremediation pad area and along the southern part of each exposure area
- Inorganics were detected in soil above one or more screening level in both exposure areas with the highest concentrations generally located in exposure area BWC-E at locations BWC-22 and BWC-53.
- Soil samples were collected for chromium speciation and hexavalent chromium was not detected in any of the samples collected.
- Pesticides were detected in soil above one or more screening levels in both exposure areas with the highest concentrations generally located in exposure area BWC-E
- No TCLP VOCs, TCLP SVOCs, or TCLP metals were detected above the TCLP regulatory levels in either the slag pile or the surface soil sample collected next to the slag pile.
- Field observations of product, staining, and odors were recorded at numerous soil boring locations with a greater number of observations generally located in exposure area BWC-E near the former bioremediation pad area and along the southern part of each exposure area
- VOCs were detected in groundwater above screening levels in exposure area BWC-E
- SVOCs were detected in groundwater above one or more screening level in both exposure areas with the highest concentrations generally located in exposure area BWC-E near the former bioremediation pad area and along the southern part of each exposure area
- Inorganics were detected in groundwater above one or more screening level in both exposure areas with a greater number of inorganics and the highest concentrations generally located in exposure area BWC-E.
- Field observations of product (LNAPL) were recorded at numerous temporary well locations with a greater number of observations generally located in exposure area BWC-E near the former bioremediation pad area and along the southern part of each exposure area
- The maximum LNAPL thickness measurement in well BWC-GW36A indicates that (1) site-related contamination may be moving westward in groundwater, (2) contamination from an off-site source may be migrating onto the western part of BWC, or (3) a smear zone may exist at the groundwater/vadose zone interface and the presence of product in BWC-GW36A may be a result of a rise or fall in groundwater elevation

- DNAPL was not measured in any of the temporary wells installed; however, LIF responses and field observations during drilling indicate that DNAPL is suspected to exist primarily at the unconsolidated material/bedrock interface at several locations
- Total risks exceed $1\text{E-}04$, the upper end of EPA's acceptable risk range for future residents, child recreationalists (surface soil only), future industrial/commercial workers, future construction workers, and future utility workers at BWC-E and for future residents (BWC-W).
- Total risks and hazards are about 1 to 2 orders of magnitude higher at BWC-E as compared to BWC-W.
- Soil risks are driven by potential exposure to BaPE and to a less extent arsenic.
- Groundwater risks for residents and industrial/commercial workers are driven by potential exposure to BaPE, and to a lesser extent, arsenic and 1-methylnaphthalene. It should be noted that at BWC-E, the following organics also contributed to groundwater risks: 1,1'-biphenyl, ethyl benzene, benzene, and n-Nitrosodiphenylamine.
- Groundwater risks for construction workers and utility workers at BWC-E are driven by potential exposure to naphthalene (via inhalation of vapors in a trench), and to a lesser extent, the same groundwater COPCs described in the preceding bullet. Groundwater risks for these same receptors are negligible at BWC-W.
- Soil hazards exceed 1 only for residents (BWC-E and BWC-W). These hazards are driven by various metals including arsenic, cadmium, cobalt, copper, iron, and manganese, as well as several PAHs (BWC-E only).
- Total risks and hazards for BWC-N (adult farmer) are similar to those calculated for the same receptor at BWC-BKG.
- Finally, total risks and hazards calculated under CTE conditions are about 3 to 10 times lower than those calculated under RME conditions, depending on the receptor considered.
- The results from the SLERA for the BWC clearly show that portions of BWC have elevated concentrations of metals, pesticides, and PAHs that may pose potentially unacceptable risks to ecological receptors. The former main plant area is the portion that showed the highest risk. However, this property is of limited ecological significance, because it is an isolated habitat that is surrounded by agricultural fields on three sides and an industrial operation to the other side. Based on this information, a BERA is not recommended for BWC site.

8.4 BWC RECOMMENDATIONS

The following recommendations pertain to BWC:

- Conduct additional rounds of NAPL and water level measurements and product fingerprint analysis to determine whether any or all of the fuel present at BWC is a result of migration from Union Tank Car
- Abandon any temporary monitoring wells that are no longer necessary
- Conduct additional sampling and analysis to determine if creosote (DNAPL) is present.

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Figures 1 through 59

Appendix A
LSR Sediment and Surface Water Field Data Sheets

Appendix B
LSR Fish Sampling Field Data Sheets

Appendix C
LSR Soil Boring Logs and Temporary Monitoring Well Sheets

Appendix D
BWC LIF Screening Logs

Appendix E
BWC Soil Boring Logs and Temporary Monitoring Well Sheets

Appendix F
BWC Groundwater Field Parameter Data Sheets

Appendix G
BWC Groundwater Level Measurements

Appendix H
BWC Professional Survey Results

Appendix I
LSR and BWC Endangered Species List

Appendix J
LSR Data Summary Tables

Appendix K
BWC Data Summary Tables

Appendix L
LSR and BWC Human Health Risk Assessment and
Screening Level Ecological Risk Assessment